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L'ECOLE POLYTECHNIQUE.

THE fêtes in honor of the centenary of l'Ecole Polytechnique have brought most prominently before the eyes of the public this institution that has won great prestige by the important part it played in the French revolutions of the last century, the pleiad of remarkable men that has come from its ranks, and the *esprit de corps* that unites the pupils. Napoleon I called it his "Hen with the golden eggs," and this hen has ever since been the emblem of the school.

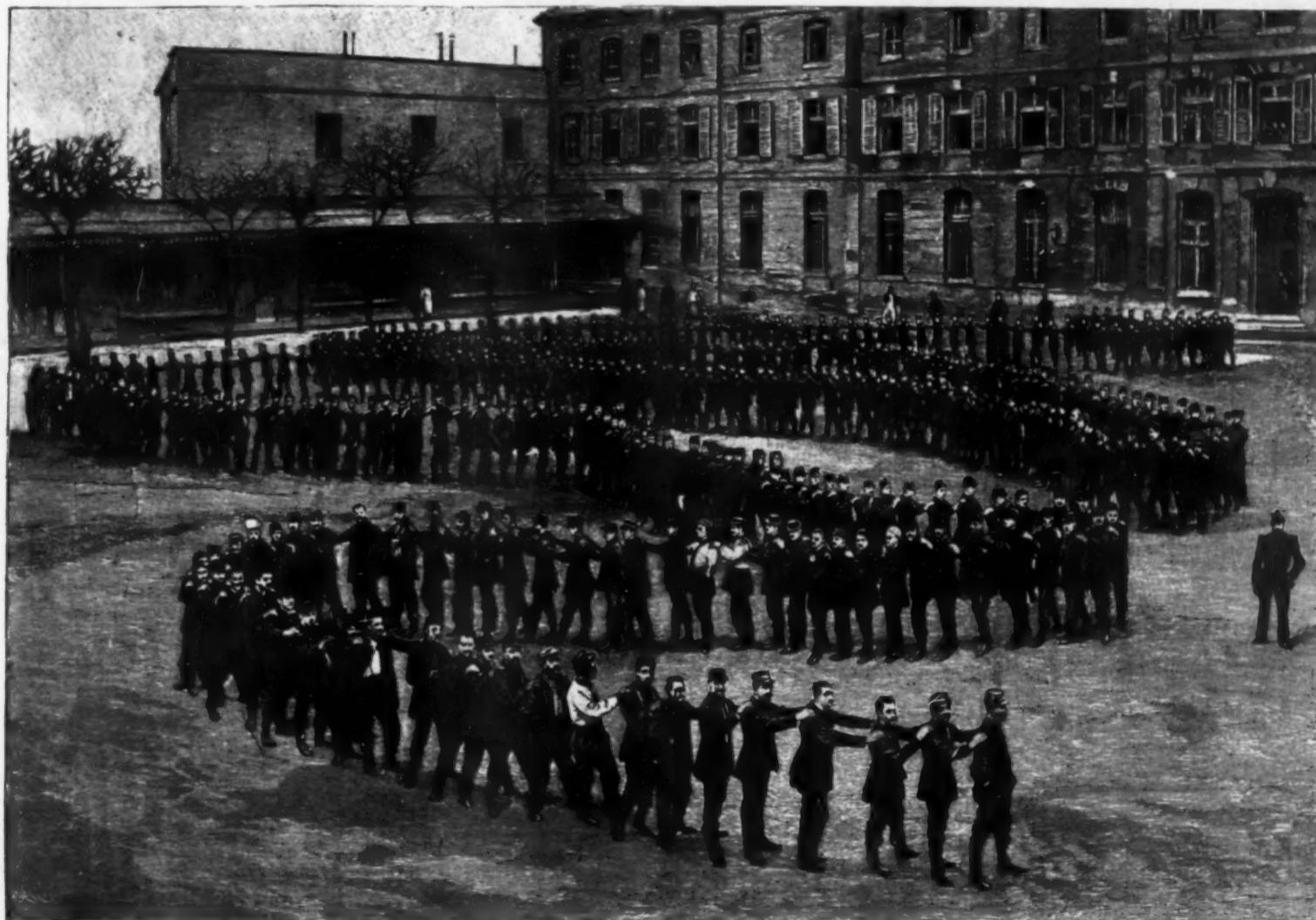
L'Ecole Polytechnique was founded during the Reign of Terror. In 1793, when France was invaded on all sides and seemed almost helpless—although many came forward to offer themselves for the cause of liberty, fraternity and equality—there were no men fitted to form the engineer corps, so that it was easy

engineering, mining, etc.—and the institution took its present name. It found many adversaries and had to pass through a most trying period. The depreciation of the assignats deprived the pupils of their income, rendering their situation precarious. In vain the richer pupils shared their fortunes with their less fortunate comrades, and M. Monge and other professors gave up their salaries; three hundred youths were obliged to return to their families. These difficulties did not break up the school, however, and the pupils were aroused to such enthusiasm by Bonaparte that they managed to raise from their meager allowances the money necessary to build the Polytechnique, a vessel that they presented to him when he was planning a descent on England.

These good relations between the school and the First Consul did not last. Napoleon was exasperated and

receive the cross of the Legion of Honor, but the pupils modestly declined this honor, saying that they did not deserve such exceptional rewards. Later the "Powder Conspiracy" was followed by grave consequences, and henceforth the monarchy of July had an irreconcilable enemy in the Ecole Polytechnique. But finally peace was restored and the school as well as France had no history for fifteen years.

The pupils again took an active part in the revolution of 1848, again acting as arbiter between the government and the people, and after performing the most delicate missions returned quietly to their studies. They maintained a quiet hatred for Napoleon III and his government. When war was declared some of the pupils were sent to Metz, others became part of the Army of Châlons, and some remained in Paris. The school was opened again in 1871, but has taken no



THE POLYTECHNICAL SCHOOL—L'ECOLE POLYTECHNIQUE—PARIS—THE MONOME.

for Carnot and Prieur to show the great need of a school for training engineers. Several schools were organized, but they did not meet the requirements, and on March 11, 1794, the Convention appointed a commission to which Carnot, Guyton-Morveau, Monge, and Prieur-Duvernais belonged—charged with the establishment of a Central School of Public Works, and on September 28, 1794, the law organizing the school was passed. A fortnight later examinations began in twenty-two cities of France. The requirements were vague, but it was considered necessary that the candidates should be remarkable for the practice of republican virtues, and should have constantly manifested a love of liberty and equality and a hatred of tyrants. The Palais-Bourbon was arranged to receive the 206 pupils admitted, and Monge opened his courses on December 10, 1794. The pupils were exterminated and received an allowance in assignats equal to about \$240. Fathers of families, good patriots, undertook to board them for \$180 each.

Some months later the school was reorganized. The prime object was no longer the education of engineers, but the preparation of pupils for the several schools of application for the different branches—artillery, en-

wished to kill the "Hen with the golden eggs," and a project was elaborated for reorganizing the institution on a new basis, but France was invaded and the polytechnicians defended the throne against the Prince of Wurtemberg with cries of "Vive l'Empereur!" Through all of this period the school played a most important role, for it became incorporated with the national guard and was always very prominent in quelling street riots.

When the first shots were fired in the revolution of July the pupils went out *en masse*, but many were brought back by their families or guardians, so that only about sixty took an active part, putting themselves at the head of the insurrection. When the battle was over the school restored order. In a few hours it had gained great popularity, banquets and fêtes were given in its honor and poets sang its praises; Reims sent champagne and American congratulations. The people, who owed victory to the school, gave it respect and affection and for twenty years relied on it for the defense of its liberties. Louis Philippe rewarded those students who had taken part in the action by advancement in the career for which they were preparing, and even proposed that twelve of their number should re-

interest in the petty party quarrels of the Third Republic.

LIFE AT THE SCHOOL.

When the school was founded little attention was paid to clothing, but later a uniform was adopted for the sake of economy, to aid in establishing equality—under the republic—and to facilitate surveillance. Since then the uniform has been changed many times. Since November 11, 1805, the institution has occupied the site of the former colleges of Navarre, Boncourt and Tournay. Then it accommodated one hundred pupils, but now it receives more than double that number. Annexes have been built, but still the accommodations are quite inadequate. Fortunately, however, the neighborhood is healthful and the young men do not seem to suffer, although it is likely that the exhaustion which sometimes follows the two years' course is due more to these unhygienic conditions than to overwork. The dormitories, which are low and lighted on only one side, contain twice as many beds as should be placed in such rooms. They are very bare; there is not a curtain at the windows nor a chair for comfort or convenience. The studying rooms offer

little more comfort. On each side of the room there is a table, and above this are a few shelves for books and racks for plans, etc.; in one corner is a table where conveniences for making punch are concealed. The only seats are massive stools. In the corners at the right and left of the glass door, where nothing can be seen from the outside, the students play whist, read the journals, and otherwise entertain themselves, but this does not interfere with work. The surveillance is paternal and the pupils are not interfered with except in case of an outrageous disturbance.

The polytechnicians have not lost the gayety of former times; the farces to which our future engineers give themselves up seem to be a necessary relief from their abstract studies, and sometimes the court

was celebrated each year by an immense masquerade called the "Fête du Point Gamma." At first the young men were contented with paper costumes to wear on these occasions, but afterward everything was done on such a grand scale that the fete was suppressed on account of the expense and loss of time. There are several other fetes, and the *monomes* are still in existence. According to Pinet the *monome* dates from 1836. The students formed the habit, during the short recreation hour in the evening, of passing through the rooms successively, collecting their comrades as they went in a long line. Later, when they wished to make a demonstration at the beginning or end of certain exercises on traditional days, a *monome* was organized. There is the *monome des fumistes* led by

absorption lasted two months, now it is over in a week, and is closed by a peculiar fete held in one of their amphitheaters. At the close of the performance the freshmen are solemnly exhorted to be true to the code of the school, which is more sensible than might be supposed.

The school is under a military regime; it is commanded by a general, assisted by a colonel, second in command, a major and six captains, having the titles of inspectors of studies. Gen. Andre, who has been in command for several months past, is from the artillery, and Colonel Roux belongs to the engineering corps. Both of them were formerly pupils of the school, and both stood No. 1 in the school of application at Metz. Major Reiset directs the military instruction. The relations between officers and pupils is delicate, but is based on mutual esteem;



DORMITORY—L'ÉCOLE POLYTECHNIQUE.

presents an odd spectacle. It is light and airy, and is closed in on three sides by the billiard rooms, barber's shop, armory and offices, while the fourth side is occupied by what is called "Pavillon des élèves." This structure was erected in 1738, and is all that remains of the ancient college of Navarre, the only one of the time, apparently, in which the pupils did more than promenade. The aspect of the court from the other side of the "pavillon" is very different. It is inclosed by the laboratories and the annexes, and is half a dozen steps lower than the other court. Part of it is used as a gymnasium and the rest as tennis courts. It is not unusual, in good weather, to see all of the pupils seated or lying in the most careless attitudes on the ground in the large court. Groups isolate themselves to play chess or backgammon, while others go to the billiard rooms, or content themselves with their pipes. Every day, except during examination times, there is a military drill, and sometimes this large space is the scene of the most burlesque performances. Formerly the vernal equinox

a freshman not yet in uniform; the *monome de manips*, where each one is dressed in a long linen blouse such as is worn during chemical experiments; and the *monome des tangents*, on the day when the pupils are exercised for the first time in the use of the sword; each one places his right hand on the shoulder of the comrade in front of him, and in his left hand he holds the sword of the one who follows. Other *monomes* of a more or less fantastic nature are imposed on the freshmen during the famous period of *absorption*.

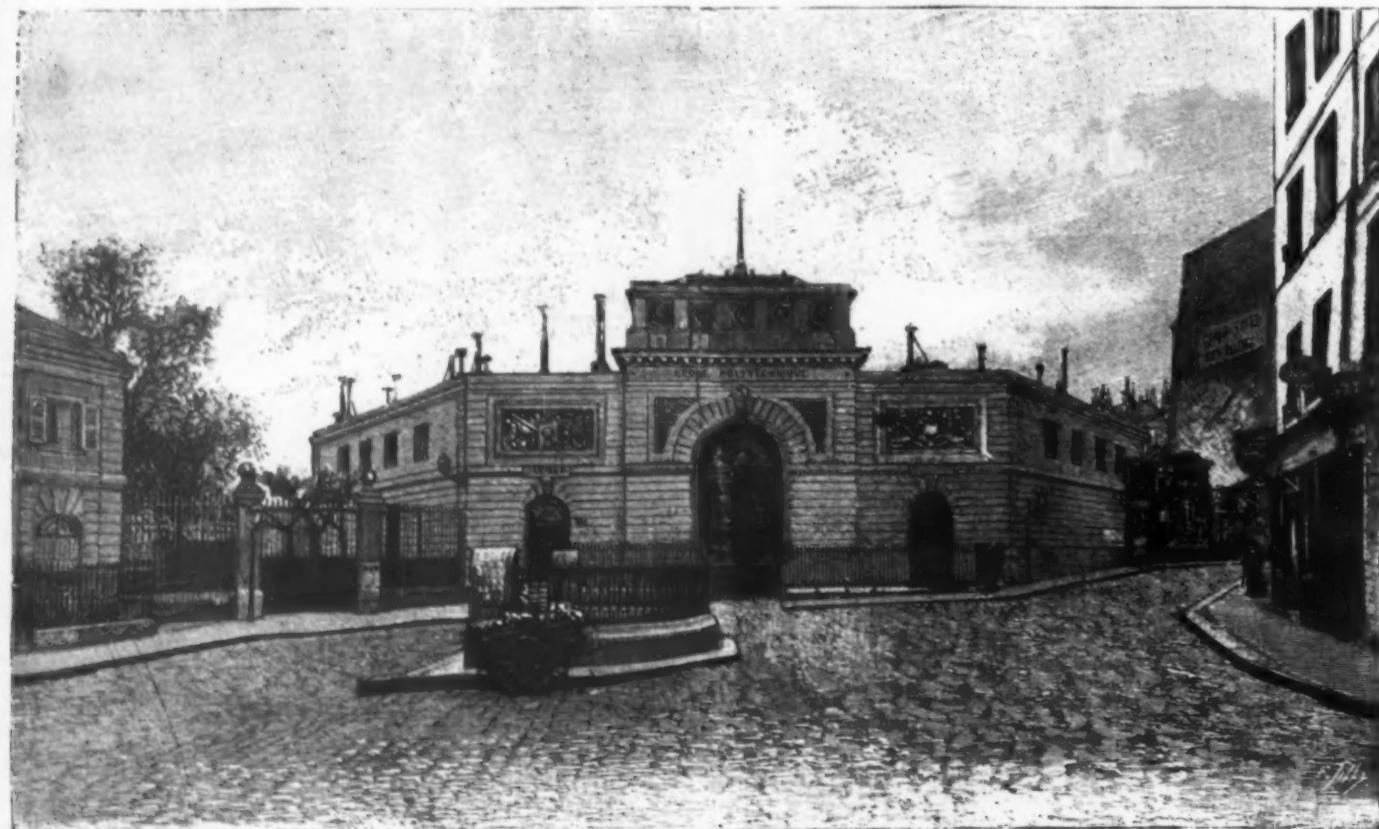
During the days of the *externe* there was little in common among the pupils, but when they became internes and were put under military discipline, they felt the necessity of a solidarity among themselves that would permit of their resisting authority on occasion. In order to *absorb* the freshmen, the older pupils subject them to a certain amount of hazing, and formerly some of the tests to which they were subjected were severe, but now they are mostly of a very innocent nature. Formerly this period of *ab-*

the authority shuts its eyes to all the doings of the pupils that do not cause too much disorder.

The refectories are cold, being in a basement, and are provided with only the necessary furniture. Three meals are provided each day, and at three p. m. every day the poor of the neighborhood go to the school for what is left by the pupils. The latter have always been charitable, and even in the earliest years of the institution, during the critical period, they had their treasury. Two pupils were chosen by their comrades, invested with discretionary power, and were not obliged to render a report to any one. They imposed a tax on their rich comrades to pay the expenses of the poorer scholars, to whom they gave even a certain amount of pocket money. Now the state supplies the necessary money, and the school treasury is used only to meet the unusual expenses. The funeral expenses of those who died in the school have always been paid from this fund. In 1890, it was combined with the beneficence bureau of the school,



UNIFORM OF PUPILS—L'ÉCOLE POLYTECHNIQUE.



L'ÉCOLE POLYTECHNIQUE, PARIS.

which was created in order to help the poor of the neighborhood. The treasurers designate the pupils who are to go Sunday mornings to carry their offering.

Another society, "L'Amicale," founded in 1864, is intended to aid comrades who have left the school and have suffered reverses. Their capital, fed by assessments, gifts and the money made by the annual ball, is now \$1,000. The members of the association meet once a year to hear the report read.

We publish several engravings, including portraits

can be pushed up and employed in this work, but more often they will not be on hand; and as infantry forms the bulk of an army, it is to it that the work of assaulting falls, and it is the arm that has to render secure the position when taken.

The preparation of a position for defense, when time and tools are available, is ordinarily made by the engineers accompanying the army. Their duties more especially belong to the class of works that have some permanent value, and not to those that have the nature

trically mixed up in the rear of the line, and they could not possibly be brought up to the point where they were so much needed. On the other hand, the Germans, recognizing the value of earthworks, proceeded to strengthen their position as soon as it was captured.

It is, then, necessary to provide other means by which, when positions are taken, they can, without delay, be placed in a state of defense; time may not allow, or circumstances may prevent, the bringing up of the tools of the pioneer or engineer corps, as in the instance quoted above; therefore the work must be done by the troops already in the position, and they must possess the tools with which to do it.

The few minutes following the taking of a position by assault are invaluable, as at this time a comparatively small amount of work may make the position so strong as to deny it to the enemy for the rest of the battle, while a neglect to so strengthen it may (and generally will) result in the unnecessary loss attendant on the taking of a position that cannot be held. Abundant time may be available, but even in villages or towns tools are not always to be found, and certainly they will not be on hand in woods or open fields. It therefore becomes a necessity to provide the needed tools and means of carrying them. First, we should decide on the tools to be used in the different cases that may arise; there are only three general cases:

1. Woods.
2. Open ground.
3. Villages or towns.

These may occur singly, but, in the general case, two and usually three will enter every field of battle.

The tools for felling trees and cutting brush are axes, bill-hooks and saws; for open ground, spades and picks; for villages, all of these, and in addition, crowbars and some means of demolishing walls and houses—such as gun-cotton or dynamite.

Now it is manifestly clear that an infantryman cannot carry all of these tools, and, upon examination, it will be found that any one of the common form is of such weight that even neglecting their size, it would be impossible to carry them in the field in addition to the other necessary burdens. We must, therefore, make the absolutely indispensable tools of such weight as will allow of their being easily carried by the soldier, while at the same time they must be strong enough to do the work required of them.

It must be understood that while these tools are not primarily intended for use in throwing up permanent works, it is possible to use them in this way if necessary; as most of the works thrown up by the Roumanian troops before Plevna in the Turko-Russian war were made with the Linneemann shovel, and thus in part they may take the place of the engineer tools. Their proper work, and the one for which they are intended, is the making of shelter in the open where none exists, or of improving such as already is present. Mayne says: "If cover cannot be obtained that will give complete protection from fire, the next best thing is cover from sight, because anything which can prevent an enemy from taking a definite aim must reduce the efficacy of his fire, so that, at all events at the commencement of a fight, any kind of cover should be sought and be made use of."

Tools must be carried by advance guards, outposts, and detached parties; for they must often hold their ground at all risks, and if they wait to be supplied from the rear, the position may be lost for want of implements to make the necessary cover.

Argument as to the necessity of intrenching tools seems almost out of place now, as almost all nations have acknowledged their necessity as fighting implements second only to the rifle; but in our army we have not as yet adopted one. The hunting knife is a substitute much in the shape of the half loaf, *i. e.*, it is better than none; but the intrenching tool proper is practically unknown to our soldiers. I have accordingly thought it proper to give drawings of as many tools as I could procure, with some discussion as to their merits and demerits, with a view to opening the question of the selection, not of a particular tool, but of some type for use.

The chief requisites of this type of tool are, first, that it shall be a good digging implement; second, that it



THE LIBRARY—L'ECOLE POLYTECHNIQUE.

of some former pupils, for which we are indebted to *L'Illustration*.

PORTABLE INTRENCHING TOOLS FOR INFANTRY.

By Lieut. W. C. WREN, 17th U. S. Infantry.

NOTE.—In the German service, normal shelter pits are considered safe against small-arm projectiles and shrapnel fragments only when there is an earth defense in front of sixty inches.

THE accuracy of modern fire-arms, their increased rapidity of fire and their great penetration, render necessary some shelter for the troops engaged on the field of battle. Natural cover may exist, and when such is found advantage should be taken of it, but usually artificial shelter must be constructed by the troops engaged in the action.

Intrenchments on the field of battle depend, as to their position, extent and use, on the ground and on the tactical advantages to be gained; and, in conformity with this idea, they are constructed at the commencement of the battle or even during its continuance. Thus it stands to reason that when the necessity becomes apparent, the intrenchments must proceed with the least possible delay; and that this may be practicable, the tools must be at hand and not in the wagons of the train. This was shown during the first part of the war between Turkey and Russia. In the various assaults on the works that surrounded Plevna, the men were driven to the utmost extremities for the want of proper intrenching tools. They were compelled to use their bayonets, mess tins, hands and knives; sometimes filling up the open spaces with the dead bodies of their own men. Portable tools at such a time would have been of the greatest importance and in the highest degree beneficial, and would have materially aided the attacking party.

During the late war in this country we found the wants in regard to intrenching tools, the men resorting to tin plates, halves of canteens and knives, in the same manner as the Russians, in order to protect themselves against the greatly inferior shooting weapon of that day. During the latter part of this same war field intrenchments received their fullest development, and a line rarely went to the front without taking such materials as could be rapidly and easily gathered, for the purpose of forming the nucleus of a breastwork. The Atlanta campaign furnished many cases of this kind of fighting, and Gen. Sherman says that even his skirmishers were accustomed to carry forward logs, rails, etc., to help intrench.

This lesson has been learned by all foreign nations; but we, the originators of the system in modern war, have completely neglected it. To-day it is generally accepted as a fact that the troops that take a position from the enemy must fortify it, or at least be able to do so; circumstances may be such that the engineers

of rifle pits and shelter trenches. To them falls the duty of repairing and destroying roads, building and destroying bridges, etc., and from the nature of their service considerable transportation in the shape of wagons is necessary. These wagons are only too often far behind; or, if in front, they are in positions from which they cannot move in safety to themselves or advantage to the other arms. At Gravelotte the right of the French line, about St. Privat, was susceptible of intrenchment and could have been strengthened enough to have made the German success at that point problematical, if not impossible. This was recognized at the time, but there were no tools in the hands of the troops, and all efforts to supply the deficiency by bringing up the engineer tool wagons were rendered abortive by the fact that the train itself was inex-



A STUDY ROOM—L'ECOLE POLYTECHNIQUE.

can be used as a cutting tool for small brush, etc., for the purpose of making fascines, etc.; and third, that in fulfilling their conditions, neither shall compromise the other.

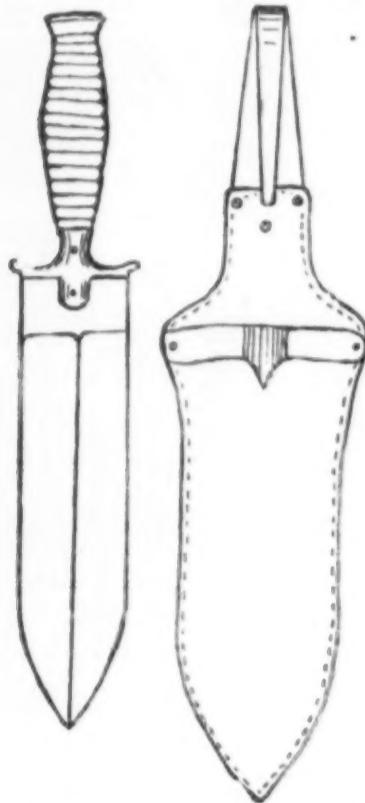
The United States Ordnance Hunting Knife and Intrenching Tool is issued to the men in the United States army for use as an intrenching tool and also as a hunting knife. Its dimensions are as follows:

Length, about 13½ in.

Length of blade, about 8½ in.

Width of blade, about 2 in.

The handle is of wood, 4½ in. long, and turned so as to give a grip for the hand; the blade has a rib running the whole length, and is sharpened one side to give a



THE UNITED STATES ORDNANCE HUNTING KNIFE AND INTRENCHING TOOL.

cutting edge, the other side being heavy and about 0.25 in. thick. The lifting surface is about 14 sq. in. The carrying case is made of very heavy leather, bound with brass, and is attached to the belt by means of a brass hook fastened to the upper part of the scabbard by three rivets; the hook tapers to a width of about 0.25 in., so as to allow of its being passed through the thimble of the field belt. Its weight is about 1 lb., or just about one-half what a serviceable shovel would weigh.

This implement is intended to be used by a man kneeling and using one or both hands as best suits his convenience. The section of the knife is not a good one for carrying earth, and in practice the man has to use his hands to throw the earth to the front.

The knife is too light to cut through sod readily, is so thin as to be bent easily, and if used in stony ground

on this tool and very generally say that they would rather carry a larger and more effective tool, even though it should weigh more.

Rice's trowel bayonet, another American intrenching tool, consists of a thin, slightly curved blade of steel welded on the ordinary bayonet. It is intended to be used as a tool for intrenching purposes, being then detached from the musket; the loop connecting the shank and base of the blade serves also as a guard for the fingers while in the act of digging. A similar blade may be attached to the ordinary sword bayonet handle, which, though much heavier than the first described, affords a more convenient grasp for the hand. While it was thought that this was a very good thing in its way, still the liability that the tool would be employed while on the muzzle of the piece caused a tool to be substituted for it that could by no means be used in this way. This tool is made of a sheet steel blade, turned up on one edge, and slightly curved cylindrically near the point; it is set in a slight wooden handle split for its reception and securely riveted through the tang of the blade. In one form of the implement the lower edge is cut into saw teeth. This form was intended for exclusive use as an intrenching tool. On the trial of the bayonet three laboring men in 4½ minutes threw up an embankment 20 in. high, 30 in. wide at the base and about 8 in. at the top, and 5½ ft. long, from an area of ground of 6½ ft. by 5½ ft. and 5 in. deep, which concealed them from observation when they lay close to the ground.

Both of these tools have the same disadvantage as the knife, *i. e.*, they are too small and light. However, the trowel bayonet is much the best of the three, in that it can be used as a sod cutter much more effectively than either of the others, and is by no means to be despised as a weapon; but in securing its lightness and portability, the other necessary qualities have been sacrificed.

The Patterson spade is intended to combine the virtues of a spade and hoe, and can be changed from one



THE PATTERSON SPADE.

to the other by turning the blade about an axis perpendicular to the handle. It consists of a heart-shaped steel blade to which is attached a lug by means of two rivets, the lug being grasped by a sleeve of brass and revolving on a bolt at right angles to the axis of the sleeve. Three holes are bored in the lug to receive the end of the handle, which is secured in the sleeve by means of a thread cut in the inside surface of the sleeve and on the outside of the handle. These holes are so arranged that inserting the handle in one gives a straight spade, in another gives the hoe, and in the last one the blade is folded back flat on the handle for convenience in carrying. A small hole in the blade allows the passing of a hook by means of which the spade is attached to the left side of the belt. The blade is about 7 in. wide by about 8 in. long, the entire length being about 20 in., and the handle having a diameter of about 1 in.; the spade weighs about 1 lb. 9 oz.

The idea may be a good one, but the sacrifice of strength necessary to accommodate the mechanical details and to get the lightness is so great as to render it unable to stand the rough work that falls to an intrenching tool, the lug being too small and the manner of attachment too insecure for use. Its weakness was shown in tests made at Fort Leavenworth, where it broke during trial, before the first sod was raised, the lug separating from the blade and shearing the rivets clean. The idea is by no means new, a spade of this kind having been invented by Captain Harrison, of the London Engineers. Harrison's blade had a pick welded to the back and top of the blade, so that, when the blade was down at right angles to the handle, the tool took the form of a hoe on one side and on the other the shape of a pick. The blade had a hole through it to admit the muzzle of the piece, allowing it to be used as a shield when the pick was driven into the ground and the blade turned up. I hardly think that this form of tool will ever be adopted for use, on account of its manifest inability, constructed as at present, to do the work required.

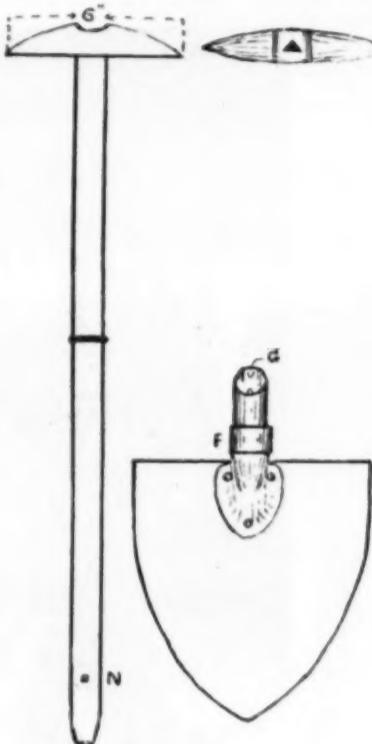
The Underwood spade, the invention of Colonel Underwood, 4th and 5th Hussars, British service, is a compromise tool combining a pick, a grubber, bayonet scabbard, rifle rest, and spade.

The handle is of steel, made hollow for the purpose of containing the bayonet, thus allowing the bayonet scabbard, usually worn, to be dispensed with; its length is 1 ft. 10½ in. and total weight is 27 oz.

The pick is of steel and is welded to the upper end of the handle; the blade is of steel, heart shaped, 8 in. long, and 7½ wide at the top, and is 1 in. thick; it weighs 24 oz.

Attached to the top of the spade blade is a socket with two lugs, the socket tapering and having a sliding collar. To assemble the spade, the handle is placed in the socket, engaging the lugs, G, in the holes, N, and then the collar is slid up over the socket, forcing the lugs home and holding them in place. The blade is carried in a leather case on the right side, and may be used as a shield by hanging it on the buttons of the coat; the inventor claims that it will deflect bullets at distances exceeding 300 yards. The handle is worn on the left side as a bayonet scabbard. The inventor in his description says that the spade has a greater digging power than the Linnemann or Wallace shovel, and

that it is strong and durable. Trials at the U. S. Infantry and Cavalry School developed weakness in the fastenings, one of the lugs breaking off during the first trial. The rifle rest is used by sticking the handle in the ground and resting the piece in the notch at the top. This spade also belongs to the compromise class, and, being in two parts, is more liable to become disabled than one complete in itself. The advantage of the long handle in digging is incontestable, but is



THE UNDERWOOD SPADE.

overbalanced by the many disadvantages of a jointed tool; for if it is once damaged in the socket or handle, it cannot be repaired in the field.

The Wallace spade is of steel, 23 in. in length, and has a steel-shod crutch handle. The steel covering of the crutch is made so that one end can be used as a pick and the other as a grubber. The blade is of steel, 7½ in. long and 5½ in. wide, and is of sufficient strength to allow of small wood being cut readily. Its weight is about 2½ pounds. The inventor claims advantages from its use as a shield at long ranges against rifle bullets, and also as a weapon at close quarters.

Some of the regiments in the British service are armed with the Wallace spade, but the men do not like it at all, as the blade cuts the trousers and the tool is awkward to carry. This could be remedied by carrying it upside down and wearing the blade up; but, even then, the crutch would be in the way. Some officers say that it can only be used in soft soil and is useless when stony ground is met with. This tool is a good one of its kind, but lightness is sacrificed to the

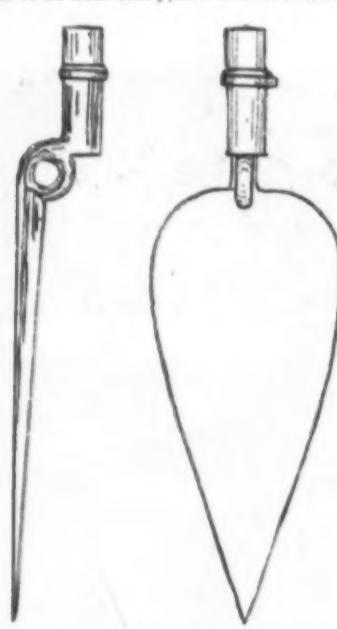


THE WALLACE SPADE.

crutch handle without a corresponding gain in efficiency, as is generally the case in all compromise tools.

The Linnemann, used by Germany, Austria, Holland, France, Russia, Roumania, Servia and Greece, is made of steel, and has a length about 20 in. over all. The blade is 6 in. wide and 8 in. long, and has one side cut into saw teeth, the other being sharpened so as to act as a cutting edge. Its weight is from about 1½ to 1¾ pounds.

Some of the countries that use this shovel think highly of the saw, but Germany, France and Russia do not use it at all, holding that it is better to carry the necessary tools of other sorts, such as picks, billhooks, saws, etc., as the compromise tool does not fulfill the conditions of all the implements represented.



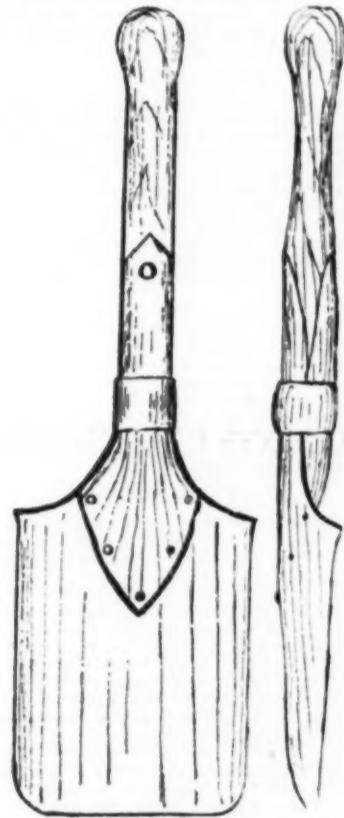
RICE'S TROWEL BAYONET.

would be soon disabled. The smallness of the blade allows so little earth to be thrown out at each stroke that the time necessary to dig a shelter pit is considerable, and the construction of any other form of shelter is entirely out of the question. Using this implement in intrenching would soon render it useless as a knife, as the edge would become so dull as to prevent its use as a cutting tool. The men set small value

In using this spade, the soldier presents his left side to the enemy, bends the right knee and takes the handle in the right hand, seizing the collar of the spade with the left hand. The shortness of the spade makes it necessary for the soldier to kneel or bend over very much. In the first case, the man is less exposed and more completely covered by the dirt thrown out; in the second case, he works more rapidly, and is able to cut the turf more readily.

The second method is generally preferred by the men when not under the fire of the enemy and when the workers are relieved every 20 minutes. In stony ground it is necessary to help the work by putting the foot on the upper part of the blade. To employ the spade as a hatchet, the soldier takes the handle near the iron part of the spade and strikes it slantingly, the strokes falling as near as possible to the flange on the upper part of the spade. Trees up to 6 in. in diameter can be felled in this way, and a hard wood tree 3 in. in diameter has been cut down in 1½ minutes. In using the saw a horizontal cut is made first with the saw and then the notch cut out with the sharp edge of the spade. In my opinion this spade presents the maximum efficiency with the minimum disadvantage. It is strong, handy and easily carried, and is a compromise in no sense of the word. Whether the saw edge is an advantage or even permissible is an open question.

So, after carefully considering each tool in this list, we find only one that fulfills the conditions imposed, and that is the Linnemann. It is a good digging tool, it can be used for cutting small brush, and it does not sacrifice either quality to the other. The Linnemann is, according to my opinion, the proper type of spade to be used; but it is not by any means necessary that we should follow the exact pattern that is used in Europe, and I think that we should gain by using the same pattern of spade that is so familiar to us all.



THE LINNEMANN SPADE.

The Continental style has too much slope to the tread to allow of placing the foot squarely, and I am of the opinion that the square tread would be much better and would not materially decrease the strength of the tool. The weight should not be over two pounds—the lighter the better, for any gain in lightness that can be made, without weakness, is a distinct gain in efficiency.

These spades can be made very cheaply, and there is no reason why they should not be issued to the infantry in sufficient numbers to allow of 75 per cent. of the men being armed with them, the other 25 per cent. to be armed with the pick and hatchet. These picks and hatchets should not weigh more than two pounds, and should be worn in leather cases as prescribed for the spade. They could be so distributed that each squad of 8 men would have 6 spades, one pick and one hatchet. This proportion would be sufficient in all but stony ground, and in such ground, picks of such size would be of little use. Even with the tools of the engineer park full sized picks would be necessary.

The average American soldier thinks that he is much overloaded at present, and regarding any further addition to his pack as an imposition, he dislikes the prospect of having to wear a spade. But the supposition that all the articles carried at present are necessary to the comfort and efficiency of the soldier is undoubtedly out of all reason, for our soldiers on the march throw away a large part of the pack, and still get along in a manner that is rather discouraging to those who insist that they *cannot* do without the so-called necessities. I would suggest that the pack be reduced in weight by taking away those articles that are really luxuries to the soldier on the march, and, in lieu of the weight thus dispensed with, I would substitute a spade that is light and at the same time efficient. Taking the weight of the spade at 2 pounds, and remembering that no efficient tool has been produced that weighs less, the pack could be reduced over

this amount by taking away only one of the articles carried, *i.e.*, the extra shoes, 2½ pounds; or, if this seems too much risk to take, then the blue shirt and undershirt, weighing together 2 pounds, might be omitted. In considering the proposed substitution, it must be remembered that, in each case, the old intrenching tool (the hunting knife), weighing one pound, would also be dispensed with, thus more than overbalancing the weight of the proposed tool. Better still, reduce the pack to the size and weight of the simple blanket roll at first without waiting for the men to fit it themselves; thus breeding the experience of our armies in the late war, where it was shown to be the only style of pack that the men would wear.

The item of weight can be set aside by reducing the pack; but there is another consideration that must be acted upon, and that is, that the men have not been accustomed to wearing intrenching tools as a permanent part of their equipment. In fact, in some companies they have never been taken out of the original boxes, and in others they are issued only on the eve of field operations. Thus the soldier unacquainted with the proper use of them justly complains of the addition of what he considers (and has been taught to believe is) an extra article to carry. I believe that the only way is to have the soldier carry the spade at all times, whether it is on the drill ground or in the field, and he must be taught that it is an necessary a part of his equipment as the rifle. Unless this is done intrenching tools will be lost in the camp fire, in the same manner as the excess of weight in the pack disappears at present. The tool should never be attached to the pack, as this may be thrown off at any time and thus the man be disarmed, but it could be worn hanging from the belt from the left side so as not to interfere with the handling of the rifle. Except on parades, reviews, and guard duty in the post, the spade should always be worn and would thus become as familiar an object as the bayonet scabbard.

The mere fact of the men having the tool, however, will not in any way teach them its use; and, therefore, thorough instruction in the manner in which it should be employed is necessary. In order thoroughly to instruct the soldier, he should be taught what value the different sorts of field intrenchments have against the rifles now in use, and the thickness of earth necessary to stop bullets at any distance; he should be shown the proper manner of using the spade, so as to employ his time to the best advantage, and then required to drill at trench digging as regularly as he at present goes through the setting up exercises. He should be taught the proper length, breadth, and depth of the different kinds of shelter, and required to dig them. Certain trenches have been practically adopted and authorized in our service by the order designating the English Field Engineering Manual as a text book. He should also be taught the use of the spade as a cutting tool in felling brush for gabions, fascines, revetments, etc., as it can be used for all these to advantage, and the large proportion of men carrying them makes possible a vastly increased rapidity in the construction of such material.

The advisability of the saw edge should be considered here, in view of the fact that comparatively large trees can be felled by its aid, and as the existence of the saw does not necessarily bind one to its use, it might be placed on the spade without diminishing the usefulness of the latter as an intrenching tool in the least. In some foreign armies the custom obtains of requiring each company to construct a certain number of yards of trench annually. In the given number of yards is included all kinds of trench used, and in this way the men learn to appreciate what these tools are and how they may be made valuable.

In regard to the use of the spade, Captain C. Von Widdern says: "In the attack, as in the defense, it is most desirable that the spade should be utilized as much as the rifle and bayonet. It is high time to accustom the infantry to consider this tool, equally with the rifle, as an arm from which it can obtain profit, not only on the defensive, to resist the attacks of the enemy, but also on the offensive, especially in order to promptly put a newly captured position in a state of defense and to thus ward off any offensive returns." Again, in regard to their use during the engagement, he says: "Even during an engagement the infantry threw up earth at every step and placed the edges of villages and woods in a state of defense, and this, too, as much on the offensive to secure the positions gained in the retreat to hold on to the ground."

The constant failure of works, made beforehand, under the impression that the line of battle will occupy them, has made it absolutely necessary that the men carry tools and know how to use them at very short notice on the field of battle; and this result cannot be obtained without very thorough drill. The main thing is to get the spades; but even if they were adopted in the United States Army they would probably suffer the fate of the many substitutes that have gone before, and be carefully treasured in the company store room, only to appear on stated occasions, for the purpose of allowing an inspector to certify that the company was equipped properly. Once issued to troops, the company commanders should be required to exercise the men in their use, and should be held responsible that they are used properly, and that the men are thoroughly instructed in all that pertains to the construction and use of hasty intrenchments. When the annual inspection of companies is made, the men should be exercised in this drill. This would show clearly how the work was done, and from it could be judged whether the men had been properly and sufficiently instructed. In this manner we could be sure that the men would, at least, have two tests annually. Companies failing in either proper selection of ground or in the proper construction of trenches should be allowed a sufficient time to come up to standard, and then be inspected by the post commander, who would submit a special report, stating whether the men were behind in their work on account of insufficient instruction or because of a large proportion of recruits lately received. In the latter case, the extra time allowed will insure their proper instruction at once; in the former case, extra drill should be imposed till all were up to the requirements. Should such an idea be carried out, we might hope, in two or three years, to find the infantry in some state of efficiency as regards this secondary but vitally important arm of that branch of the service.

[Continued from SUPPLEMENT, No. 968, page 15474.]

THE WORK OF HERTZ*.

MICROPHONIC DETECTORS.

RECEIVERS or detectors which for the present I temporarily call microphonic are liable to respond best to the more rapid vibrations. Their sensitiveness is to me surprising, though of course it does not approach the sensitiveness of the eye; at the same time, I am by no means sure that the eye differs from them in kind. It is these detectors that I wish specially to bring to your notice.

Prof. Minchin, whose long and patient work in connection with photoelectricity is now becoming known, and who has devised an instrument more sensitive to radiation than even Boys' radio-micrometer, in that it responds to the radiation of a star while the radio-micrometer does not, found some years ago that some of his light-excitable cells lost their sensitiveness capriciously on tapping; and later he found that they frequently regained it again while Mr. Gregory's Hertz-wave experiments were going on in the same room.

These "impulsion cells," as he terms them, are troublesome things for ordinary persons to make and work with—at least I have never presumed to try—but in Mr. Minchin's hands they are surprisingly sensitive to electric waves.†

The sensitiveness of selenium to light is known to every one, and Mr. Shelford Bidwell has made experiments on the variations of conductivity exhibited by a mixture of sulphur and carbon.

Nearly four years ago M. Edouard Branly found that a burnished coat of porphyritic copper spread on glass diminished its resistance enormously, from some millions to some hundreds of ohms, when it was exposed to the neighborhood, even the distant neighborhood, of Leyden jar or coil sparks. He likewise found that a tube of metallic filings behaved similarly, but that this recovered its original resistance on shaking. Mr. Croft exhibited this fact recently at the Physical Society. Branly also made pastes and solid rods of filings in Canada balsam and in sulphur, and found them likewise sensitive.‡

With me the matter arose somewhat differently, as an outcome of the air-gap detector employed with an electroscope by Boltzmann. For I had observed in 1889 that two knobs sufficiently close together, far too close to stand any voltage such as an electroscope can show, could, when a spark passed between them, actually cohere; conducting an ordinary bell-ringing current if a single voltaic cell was in circuit; and, if there was no such cell, exhibiting an electromotive force of their own sufficient to disturb a low resistance galvanometer vigorously, and sometimes requiring a faintly perceptible amount of force to detach them. The experiment was described to the Institution of Electrical Engineers, and Prof. Hughes said he had observed the same thing.

COHERER IN OPEN, RESPONDING TO FEELBLE STIMULI; SMALL SPHERE, GAS LIGHTER, DISTANT SPHERE, ELECTROPHORUS.

Well this arrangement, which I call a coherer, is the most astonishingly sensitive detector of Hertz waves. It differs from the actual air gap in that the insulating film is not really insulating; the film breaks down not only much more easily, but also in a less discontinuous and more permanent manner than an air gap. A tube of filings, being a series of bad contacts, clearly works on the same plan; and though a tube of filings is by no means so sensitive, yet it is in many respects easier to work with, and, except for very feeble stimuli, is more metrical. If the filings used are coarse, say turnings or borings, the tube approximates to a single coherer; if they are fine it has a larger range of sensitiveness. In every case what these receivers feel are sudden jerks of current; smooth sinuous vibrations are ineffective. They seem to me to respond best to waves a few inches long, but doubtless that is determined chiefly by the dimensions of some conductor with which they happen to be associated.

FILINGS IN OPEN, RESPONDING TO SPHERE, TO ELECTROPHORUS, TO SPARK FROM GOLD LEAF ELECTROSCOPE.

I picture to myself the action as follows. Suppose two fairly clean pieces of metal in light contact—say two pieces of iron—connected to a single voltaic cell; a film of what may be called oxide intervenes between the surfaces, so that only an insignificant current is allowed to pass, because a volt or two is insufficient to break down the insulating film except perhaps at one or two atoms. If the film is not permitted to conduct at all, it is not very sensitive; the most sensitive condition is attained when an infinitesimal current passes, strong enough just to show on a moderate galvanometer.

Now let the slightest surging occur, say by reason of a sphere being charged and discharged at a distance of forty yards, the film at once breaks down—perhaps not completely, that is a question of intensity—but permanently. As I imagine, more molecules get within each other's range, incipient cohesion sets in, and the momentary electric quiver acts as it were as a flux. It is a singular variety of electric welding. A stronger stimulus enables more molecules to hold on, the process is surprisingly metrical; and as far as I roughly know at present, the change of resistance is proportional to the energy of the electric radiation from a source of given frequency.

It is to be specially noted that the battery current is not needed to effect the cohesion, only to demonstrate it. The battery can be applied after the spark has occurred, and the resistance will be found changed as much as if the battery had been on all the time.

The incipient cohesion electrically caused can be mechanically destroyed. Sound vibrations, or any other feeble mechanical disturbances, such as scratches or taps, are well adapted to restore the contact to its original high-resistance sensitive condition. The more feeble the electrical disturbance the slighter is the cor-

* A lecture delivered at the Royal Institution on Friday, June 1, by Prof. Oliver Lodge, F.R.S.—*Nature*.

† *Phil. Mag.*, vol. 31, p. 223.

‡ E. Branly, *Comptes Rendus*, vol. 111, p. 785; and vol. 112, p. 90.

§ *Journal Inst. E. E.*, 1890, vol. 18, pp. 322-4; or "Lightning Conductors and Lightning Guards" (Whittaker), pp. 388-9.

responding mechanical stimulus needed for restoration. When working with the radiating sphere at a distance of forty yards out of window, I could not for this reason shout to my assistant, in order to cause him to press the key of the coil and make a spark, but I showed him a duster instead, this being a silent signal which had no disturbing effect on the coherer or tube of filings. I mention forty yards, because that was one of the first outdoor experiments; but I should think that something more like half a mile was nearer the limit of sensitiveness. However, this is a rash statement not at present verified. At forty yards the exciting spark could be distinctly heard, and it was interesting to watch the spot of light begin its long excursion and actually travel a distance of two or three inches before the sound arrived. This experiment proved definitely enough that the efficient cause traveled quicker than sound, and disposed completely of any skeptical doubts as to the sound waves being perhaps the real cause of the phenomenon.

Invariably, when the receiver is in good condition, sound or other mechanical disturbance acts one way, viz., in the direction of increasing resistance, while electrical radiation or jerks act the other way, decreasing it. While getting the receiver into condition, or when it is getting out of order, vibrations and sometimes electric discharges act irregularly, and an occasional good shaking does the filings good.

I have taken rough measurements of the resistance, by the simple process of restoring the original galvanometer deflection by adding or removing resistance coils. A half-inch tube, eight inches long, of selected iron turnings, had a resistance of 2,500 ohms in the sensitive state. A feeble stimulus, caused by a distant electrophorus spark, brought it down 400 ohms. A rather stronger one reduced it by 500 and 600, while a trace of spark given to a point of the circuit itself ran it down 1,400 ohms.

This is only to give an idea of the quantities. I have not yet done any seriously metrical experiments.

From the wall diagram which summarizes the various detectors, and which was prepared a month or so ago, I see I have omitted selenium, a substance which in certain states is well known to behave to visible light as these other microphonic detectors behave to Hertz waves.

And I want to suggest that quite possibly the sensitiveness of the eye is of the same kind. As I am not a physiologist, I cannot be seriously blamed for making wild and hazardous speculations in that region. I therefore wish to guess that some part of the retina is an electrical organ, say like that of some fishes maintaining an electromotive force which is prevented from stimulating the nerves solely by an intervening layer of badly conducting material, or of conducting material with gaps in it; but that when light falls upon the retina these gaps become more or less conducting, and the nerves are stimulated.

I do not feel clear which part is taken by the rods and cones and which part by the pigment cells; I must not try to make the hypothesis too definite at present.

If I had to make a demonstration model of the eye on these lines, I should arrange a little battery to excite a frog's nerve and muscle preparation through a circuit completed all except a layer of filings or a single bad contact. Such an arrangement would respond to Hertz waves. Or if I wanted actual light to act instead of grosser waves, I would use a layer of selenium.

But the bad contact and the Hertz waves are the most instructive, because we do not at present really know what the selenium is doing, any more than what the retina is doing.

And observe that (to my surprise, I confess) the rough outline of a theory of vision thus suggested is in accordance with some of the principal views of the physiologist Hering. The sensation of light is due to the electrical stimulus; the sensation of black is due to the mechanical or tapping-back stimulus. Darkness is physiologically not the mere cessation of light. Both are positive sensations, and both stimuli are necessary; for until the filings are tapped back vision is persistent. In the eye model the period of mechanical tremor should be say 1-10th second, so as to give the right amount of persistence of impression.

EYE MODEL WITH ELECTRIC BELL ON BOARD.

No doubt in the eye the tapping back is done automatically by the tissues, so that it is always ready for a new impression, until fatigued. And by mounting an electric bell on other vibrator on the same board as a tube of filings, it is possible to arrange so that a feeble electric stimulus shall produce a feeble steady effect, a stronger stimulus a stronger effect, and so on, the tremor asserting its predominance and bringing the spot back whenever the electric stimulus ceases.

An electric bell thus close to the tube is, perhaps, not the best vibrator; clockwork might do better, because the bell contains in itself a jerky current, which produces one effect, and a mechanical vibration, which produces an opposite effect; hence the spot of light can hardly keep still. By lessening the vibration—say by detaching the bell from actual contact with the board, the electric jerks of the intermittent current drive the spot violently up the scale; mechanical tremor brings it down again.

You observe that the eye on this hypothesis is, in electrometer language, heterostatic. The energy of vision is supplied by the organism, the light only pulls a trigger. Whereas the organ of hearing is idiosyncratic. I might draw further analogies, about the effect of blows or disorder causing irregular conduction and stimulation, of the galvanometer in the one instrument, of the brain cells in the other.

A handy portable exciter of electric waves is one of the ordinary hand electric gas lighters, containing a small revolving doubler—*i. e.*, an inductive or repolarizing machine. A coherer can feel a gas lighter across a lecture theater. Minchin often used them for stimulating his impulsion cells. I find that, when held near, they act a little before the spark occurs, plainly because of the little incipient sparks at the brushes or tinfoil contacts inside. A Voss machine acts similarly, giving a small deflection while working up before it starts.

And notice here that our model eye has a well-defined range of vision. It cannot see waves too long for it.

HOLTZ SPARKS NOT EXCITING TUBE; EXCEPT BY HELP OF A POLISHED KNOB.

The powerful disturbance caused by the violent flashes of a Wimshurst or Voss machine it is blind to. If the knobs of the machine are well polished, it will respond to some high harmonics due to the vibrations in the terminal rods; and these are the vibrations to which it responds when excited by a coil. The coil should have knobs instead of points. Sparks from points or dirty knobs hardly excite the coherer at all. But hold a well-polished sphere or third knob between even the dirty knobs of a Voss machine, and the coherer responds at once to the surges got up in it.

ELECTROPHORUS LID AND INSULATED SPHERE.

Feeble short sparks again are often more powerful excitors than are strong long ones. I suppose because they are more sudden.

This is instructively shown with an electrophorus lid. Spark it to a knuckle, and it does very little. Spark it to a knob, and it works well. But now spark it to an insulated sphere, there is some effect. Discharge the sphere, and take a second spark, without recharging the lid. Do this several times; and at last, when the spark is inaudible, invisible, and otherwise imperceptible, the coherer some yards away responds more violently than ever, and the spot of light rushes from the scale.

If a coherer be attached by a side wire to the gas pipes, and an electrophorus spark be given to either the gas pipes or the water pipes, or even to the hot-water system, in another room of the building, the coherer responds.

In fact, when thus connected to gas pipes, one day when I tried it, the spot of light could hardly keep five seconds still. Whether there was a distant thunderstorm, or whether it was only picking up telegraphic jerks, I do not know. The jerk of turning on or off an extra Swan lamp can affect it when sensitive. I hope to try for long-wave radiation from the sun, filtering out the ordinary well-known waves by a blackboard or other sufficiently opaque substance.

We can easily see the detector respond to a distant source of radiation now, *viz.*, to a 6 in. sphere placed in the library between coil knobs.

PORTABLE DETECTOR.

Also I exhibit a small complete detector made by my assistant, Mr. Davies, which is quite portable and easily set up. The essentials are all in a copper cylinder three inches by two. A bit of wire a few inches long, pegged into it, helps it to collect waves. It is just conceivable that at some distant date, say by dint of inserting gold wires or powder in the retina, we may be enabled to see waves which at present we are blind to.

Observe how simple the production and detection of Hertz waves are now. An electrophorus or a frictional machine serves to excite them; a voltaic cell, a rough galvanometer and a bad contact, serve to detect them. Indeed they might have been observed at the beginning of the century, before galvanometers were known. A frog's leg or an iodide of starch paper would do almost as well.

A bad contact was at one time regarded as a simple nuisance, because of the singularly uncertain and capricious character of the current transmitted by it. Hughes observed its sensitiveness to sound waves, and it became the microphone. Now it turns out to be sensitive to electric waves, if it be made of any oxidizable metal (not of carbon), and we have an instrument which might be called a micro-something, but which, as it appears to act by cohesion, I call at present a coherer. Perhaps some of the capriciousness of an anamathematized bad contact was sometimes due to the fact that it was responding to stray electric radiation.

The breaking down of cohesion by mechanical tremor is an ancient process, observed on a large scale by engineers in railway axles and girders; indeed, the cutting of small girders by persistent blows of hammer and chisel reminded me the other day of the tapping back of our cohering surfaces after they have been exposed to the breaking effect of the electric jerk.

PUT COPPER HAT OVER TUBE. SHUT UP EVERYTHING IN BOX COMPLETELY.

If a coherer is shut up in a complete metal inclosure, waves cannot get at it, but if wires are led from it to an outside ordinary galvanometer, it remains nearly as sensitive as it was before (nearly, not quite), for the circuit picks up the waves, and they run along the insulated wires into the closed box. To screen it effectively it is necessary to inclose battery and galvanometer and every bit of wire connection; the only thing that may be left outside is the needle of the galvanometer. Accordingly here we have a compact arrangement of battery and coil and coherer, all shut up in a copper box. The coil is fixed against the side of the box at such height that it can act conveniently on an outside suspended compass needle. The slow action of the coil has no difficulty in getting through copper, as every one knows; only a perfect conductor could screen off that, but the Hertz waves are effectively kept out by sheet copper.

CHINK; ROUND HOLE; PROTRUDING WIRE.

It must be said, however, that the box must be exceedingly well closed for the screening to be perfect. The very narrowest chink permits their entrance, and at one time I thought I should have to solder a lid on before they could be kept entirely out. Clamping a copper lid on to a flange in six places was not enough. But by the use of pads of tinfoil, chinks can be avoided, and the inside of the box becomes then electrically dark.

If even an inch of the circuit protrudes, it at once becomes slightly sensitive again; and if a single branch wire protrudes through the box, provided it is insulated where it passes through, the waves will utilize it as a speaking tube, and run blithely in. And this whether the wire be connected to anything inside or not, though it acts more strongly when connected.

RECEIVER, HAT AND METAL TUBE FOR CONNECTING WIRES.

If wires are to be taken out of the box to a coherer in some other inclosure, they must be inclosed in a

metal tube, and this tube must be well connected with the metal of both inclosures, if nothing is to get in but what is wanted.

Similarly, when definite radiation is desired, it is well to put the radiator in a copper hat, open in only one direction. And in order to guard against reflected and collateral surges running along the wires which pass outside to the coil and battery, as they are liable to do, I am accustomed to put all these things in a packing case lined with tinfoil, to the outside of which the sending hat is fixed, and to pull the key of the primary exciting circuit by a string from outside.

SENDER IN HAT AND BOX, WITH LID (ADJUSTABLE CLAMPED ON).

Even then, with the lid of the hat well clamped on, something gets out, but it is not enough to cause serious disturbance of qualitative results. The sender must evidently be thought of as emitting a momentary blaze of light which escapes through every chink. Or, indeed, since the waves are some inches long, the difficulty of keeping them out of an inclosure may be likened to the difficulty of excluding sound; though the difficulty is not quite so great as that, since a reasonable thickness of metal is really opaque. I fancied once or twice I detected a trace of transparency in such metal sheets as ordinary tinfoil, but unnoticed chinks elsewhere may have deceived me. It is a thing easy to make sure of as soon as I have more time.

One thing in this connection is noticeable, and that is how little radiation gets either in or out of a small round hole. A narrow, long chink in the receiver box lets in a lot; a round hole the size of a shilling lets in hardly any, unless indeed a bit of insulated wire protrudes through it like a collecting ear trumpet.

GAS LIGHTER WITH TINFOIL.

It may be asked how the waves get out of the metal tube of an electric gas lighter. But they do not; they get out through the handle, which, being of ebonite, is transparent. Wrap up the handle tightly in tinfoil, and a gas lighter is powerless.

OPTICAL EXPERIMENTS.

And now, in conclusion, I will show some of the ordinary optical experiments with Hertz waves, using as source either one of two devices: Either a 6-in. sphere with sparks to ends of a diameter, an arrangement which emits 9-in. waves, but of so dead-beat a character that it is wise to inclose it in a copper hat to prolong them, and send them out in the desired direction; or else a 2-in. hollow cylinder with spark knobs at ends of an internal diameter. This last emits 3-in. waves of a very fairly persistent character, but with nothing like the intensity of one of the outside radiators.

As receiver there is no need to use anything sensitive; so I employ a glass tube full of coarse iron filings, put at the back of a copper hat with its mouth turned well askew to the source, which is put outside the door at a distance of some yards, so that only a little direct radiation can reach the tube. Sometimes the tube is put lengthways in the hat instead of crossways, which makes it less sensitive, and has also the advantage of doing away with the polarizing or rather analyzing power of a crossway tube.

VARIOUS APERTURES IN LID.

The radiation from the sphere is still too strong, but it can be stopped down by a diaphragm plate with holes in it of varying size clamped on the sending hat.

REFLECTING PLATE, WET CLOTH, GLASS PLATE.

Having thus reduced the excursion of the spot of light to a foot or so, a metal plate is held as reflector, and at once the spot travels a couple of yards. A wet cloth reflects something, but a thin glass plate, if dry, reflects next to nothing, being, as is well known, too thin to give anything but "the black spot." I have fancied that it reflects something of the 3-in. waves.

REFRACTING PRISM AND LENS.

A block of paraffin about a cubic foot in volume is cast into the shape of a prism with angles 75°, 60° and 45°. Using the large angle, the rays are refracted into the receiving hat, and produce an effect much larger than when the prism is removed.

An ordinary 9-in. glass lens is next placed near the source, and by means of the light of a taper it is focused between source and receiver. The lens is seen to increase the effect.

ARAGO DISK, GRATING AND ZONE PLATE.

The lens helps us to set correctly an 18-in. circular copper disk in position for showing the bright diffraction spot. Removing the disk, the effect is much the same as when it was present. Add the lens, and the effect is greater. With a diffraction grating of copper strips two inches broad, and two inches apart, I have not yet succeeded in getting good results. It is difficult to get sharp nodes and interference effects with these sensitive detectors in a room. I expect to do better when I can try out-of-doors, away from so many reflecting surfaces; indoors it is like trying delicate optical experiments in a small whitewashed chamber well supplied with looking glasses; nor have I ever succeeded in getting clear concentration with this zone plate having Newton rings fixed to it in tinfoil. But really there is nothing of much interest now in diffraction effects except the demonstration of the waves and the measure of their length. There was immense interest in Hertz's time, because then the wave character of the radiation had to be proved; but every possible kind of wave must give interference and diffraction effects, and their theory is, so to say, worked out. More interest attaches to polarization, double refraction and dispersion experiments.

POLARIZING AND ANALYZING GRIDS.

Polarization experiments are easy enough. Radiation from a sphere is already strongly polarized, and the tube acts as a partial analyzer, responding much more vigorously when its length is parallel to the line of sparks than when they are crossed; but a convenient extra polarizer is a grid of wires something like what was used by Hertz, only on a much smaller scale; say an 18-in. octagonal frame of copper strip with a harp of parallel copper wires. The spark line of the radiator being set at 45°, a vertical grid placed over receiver re-

duces the deflection to about one-half, and a crossed grid over the source reduces it to nearly nothing.

Rotating either grid a little rapidly increases the effect, which becomes a maximum when they are parallel. The interposition of a third grid, with its wires at 45° between two crossed grids, restores some of the obliterated effect.

Radiation reflected from a grid is strongly polarized, in a plane normal of course, to that of the radiation which gets through it. They are thus analogous in their effect to Nicols, or to a pile of plates.

The electric vibrations which get through these grids are at right angles to the wires. Vibrations parallel to the wires are reflected or absorbed.

REFLECTING PRISM.

To demonstrate that the so-called plane of polarization of the transmitted radiation is at right angle to the electric vibration, *i. e.*, that the wires of the grid are parallel to it, I use the same paraffin prism as before, but this time I use its largest face as a reflector, and set it at something near the polarizing angle. When the line of wires is parallel to the plane of incidence, in which case the electric vibrations are perpendicular to the plane of incidence, plenty of radiation is reflected by the paraffin face. Turning the grid so that the electric vibrations are in the plane of incidence, we find that the paraffin surface set at the proper angle is able to reflect hardly anything. In other words, the vibrations contemplated by Fresnel are the electric vibrations; those dealt with by McCullagh are the magnetic ones.

Thus are some of the surmises of genius verified and made obvious to the wayfaring man.

THE SCIENTIFIC WORK OF TYNDALL.†

By the Right Hon. Lord RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., M.R.I., Professor of Natural Philosophy, R. I.

It is fitting that the present season should not pass without reference on these evenings to the work of him whose tragic death a few months since was felt as a personal grief and loss by every member of the Royal Institution. With much diffidence I have undertaken the task to-night, wishing that it had fallen to one better qualified by long and intimate acquaintance to do justice to the theme. For Tyndall was a personality of exceeding interest. He exercised an often magical charm upon those with whom he was closely associated, but when his opposition was aroused, he showed himself a keen controversialist. My subject of to-night is but half the story.

Even the strictest devotion of the time at my disposal to a survey of the scientific work of Tyndall will not allow of more than a very imperfect and fragmentary treatment. During his thirty years of labor within these walls he ranged over a vast field, and accumulated results of a very varied character, important not only to the cultivators of the physical sciences, but also to the biologist. All that I can hope to do is to bring back to your recollection the more salient points of his work, and to illustrate them where possible by experiments of his own devising.

In looking through the catalogue of scientific papers issued by the Royal Society, one of the first entries under the name of Tyndall relates to a matter comparatively simple, but still of some interest. It has been noticed that when a jet of liquid is allowed to play into a receiving vessel, a good deal of air is sometimes carried down with it, while at other times this does not happen. The matter was examined experimentally by Tyndall, and he found that it was closely connected with the peculiar transformation undergone by jet of liquid which had been previously investigated by Savart. A jet as it issues from the nozzle is at first cylindrical, but after a time it becomes what the physiologists call *curvose*; it swells in some places and contracts in others. This effect becomes more exaggerated as the jet descends, until the swellings separate into distinct drops, which follow one another in single file. Savart showed that under the influence of vibration the resolution into drops takes place more rapidly, so that the place of resolution travels up closer to the nozzle.

Tyndall's observation was that the carrying down of air required a jet already resolved into drops when it strikes the liquid. I hope to be able to show you the experiment by projection upon the screen. At the present moment the jet is striking the water in the tank previous to resolution into drops, and is therefore carrying down no air. If I operate on the nozzle with a vibrating tuning fork, the resolution occurs earlier, and the drops now carry down with them a considerable quantity of air.

Among the earlier of Tyndall's papers are some relating to ice, a subject which attracted him much, probably from his mountaineering experiences. About the time of which I am speaking Faraday made interesting observations upon a peculiar behavior of ice, afterward called by the name of regelation. He found that if two pieces of ice were brought into contact, they stuck or froze together. The pressure required to produce this effect need not be more than exceedingly small. Tyndall found that if fragments of ice are squeezed they pack themselves into a continuous mass. We have here some small ice in a mould, where it can be subjected to a powerful squeeze. The ice under this operation will be regelated, and a mass obtained which may appear almost transparent, and as if it had never been fractured at all. The flow of glaciers has been attributed to this action, the fractures which the stresses produce being mended again by regelation. I should say, perhaps, that the question of glacier motion presents difficulties not yet wholly explained. There can be no doubt, however, that regelation plays an important part.

Another question treated by Tyndall is the manner in which ice first begins to melt under the action of a beam of light passing into it from an electric lamp. Ice usually melts by conducted heat, which reaches first the outside layers. But if we employ a beam from an electric lamp, the heat will reach the ice not only outside, but internally, and the melting will begin at certain points in the interior. Here we have a slab of

ice which we project upon the screen. We see that the melting begins at certain points, which develop a crystallized appearance resembling flowers. They are points in the interior of the ice, not upon the surface. Tyndall found that when the ice gives way at these internal points there is a formation of apparently empty space. He carefully melted under water such a piece of ice, and found that when the cavity was melted out there was no escape of air, proving that the cavity was really vacuous.

Various speculations have been made as to the cause of this internal melting at definite points, but here again I am not sure if the difficulty has been altogether removed. One point of importance brought out by Tyndall relates to the plane of the flowers. It is parallel to the direction in which the ice originally froze, that is, parallel to the original surface of the water from which it was formed.

I must not dwell further upon isolated questions, however interesting; but will pass on at once to our main subject, which may be divided into three distinct parts, relating namely to heat, especially dark radiation, sound, and the behavior of small particles, such as compose dust, whether of living or dead matter.

The earlier publications of Tyndall on the subject of heat are for the most part embodied in his work entitled "Heat as a Mode of Motion." This book has fascinated many readers. I could name more than one now distinguished physicist who drew his first scientific nutriment from it. At the time of its appearance the law of the equivalence of heat and work was quite recently established by the labors of Mayer and Joule, and had taken firm hold of the minds of scientific men; and a great part of Tyndall's book may be considered to be inspired by and founded upon this first law of thermodynamics. At the time of publication of Joule's labors, however, there seems to have been a considerable body of hostile opinion, favorable to the now obsolete notion that heat is a distinct entity called caloric. Looking back, it is a little difficult to find out who were responsible for this reception of the theory of caloric. Perhaps it was rather the popular writers of the time than the first scientific authorities. A scientific worker, especially if he devotes himself to original work, has not time to examine for himself all questions, even those relating to his own department, but must take something on trust from others whom he regards as authorities. One might say that a knowledge of science, like a knowledge of law, consists in knowing where to look for it. But even this kind of knowledge is not always easy to obtain. It is only by experience that one can find out who are most entitled to confidence. It is difficult now to understand the hesitation that was shown in fully accepting the doctrine that heat is a mode of motion, for all the great authorities, especially in England, seem to have favored it. Not to mention Newton and Cavendish, we have Rumford making almost conclusive experiments in its support. Davy accepting it, and Young, who was hardly ever wrong, speaking of the antagonistic theory almost with contempt. On the Continent, perhaps, and especially among the French school of chemists and physicists, caloric had more influential support.

As has been said, a great part, though not the whole of Tyndall's work, was devoted to the new doctrine. Much relates to other matters, such as radiant heat. Objection has been taken to this phrase, not altogether without reason; for it may be said that when heat it is not radiant, and while radiant it is not heat. The term dark radiation, or dark radiance as Newcombe calls it, is preferable, and was often used by Tyndall. If we analyze, as Newton did, the components of light, we find that only certain parts are visible. The invisible parts produce, however, as great, or greater, effects in other ways than do the visible parts. The heating effect, for example, is vastly greater in the invisible region than in the visible. One of the experiments that Tyndall devised in order to illustrate this fact I hope now to repeat. He found that it was possible by means of a solution of iodine in bisulphide of carbon to isolate the invisible rays. This solution is opaque to light; even the sun could not be seen through it; but it is very fairly transparent to the invisible ultra-red radiation. By means of a concave reflector I concentrate the rays from an arc lamp. In their path is inserted the opaque solution, but in the focus of invisible radiation the heat developed is sufficient to cause the inflammation of a piece of gun cotton.

Tyndall varied this beautiful experiment in many ways. By raising to incandescence a piece of platinum foil, he illustrated the transformation of invisible into visible radiation.

The most important work, however, that we owe to Tyndall in connection with heat is the investigation of the absorption by gaseous bodies of invisible radiation. Melloni had examined the behavior of solid and liquid bodies, but not of gaseous. He found that transparent bodies like glass might be very opaque to invisible radiation. Thus, as we all know, a glass screen will keep off the heat of a fire, while if we wish to protect ourselves from the sun, the glass screen would be useless. On the other hand, rock salt freely transmits invisible radiation. But nothing had been done on the subject of gaseous absorption, when Tyndall attacked this very difficult problem. Some of his results are shown in the accompanying table. The absorption of the ordinary non-condensable, or rather not easily condensable, gases—for we must not talk of non-condensable gases now, least of all in this place—the absorption of these gases is very small; but when we pass to the more compound gases, such as nitric oxide, we find the absorption much greater—and in the case of olefiant gas we see that the absorbing power is as much as 6,000 times that of the ordinary gases.

	Relative absorption at 1 in. pressure.
Air	1
Oxygen	1
Nitrogen	1
Hydrogen	1
Carbonic acid	972
Nitric oxide	1090
Ammonia	5460
Olefiant gas	6030

There is one substance as to which there has been a great diversity of opinion—aqueous vapor. Tyndall found that aqueous vapor exercises a strong power of

absorption—strong relatively to that of the air in which it is contained. This is, of course, a question of great importance, especially in relation to meteorology. Tyndall's conclusions were vehemently contested by many of the authorities of the time, among whom was Magnus, the celebrated physicist of Berlin. With a view to this lecture I have gone somewhat carefully into this question, and I have been greatly impressed by the care and skill showed by Tyndall, even in his earlier experiments upon this subject. He was at once sanguine and skeptical—a combination necessary for success in any branch of science. The experimentalist who is not skeptical will be led away on a false tack and accept conclusions which he would find it necessary to reject were he to pursue the matter further; if not sanguine, he will be discouraged altogether by the difficulties encountered in his earlier efforts, and so arrive at no conclusion at all. One criticism, however, may be made. Tyndall did not at first describe with sufficient detail the method and the precautions which he used. There was a want of that precise information necessary to allow another to follow in his steps. Perhaps this may have been due to his literary instinct, which made him averse from overloading his pages with technical experimental details.

The controversy above referred to I think we may now consider to be closed. Nobody now doubts the absorbing power of aqueous vapor. Indeed the question seems to have entered upon a new phase; for in a recent number of Wiedemann's "Annalen," Paschen investigates the precise position in the spectrum of the rays which are absorbed by aqueous vapor.

I cannot attempt to show you here any of the early experiments on the absorption of vapors. But some years later Tyndall contrived an experiment, which will allow of reproduction. It is founded on some observations of Graham Bell, who discovered that various bodies became sonorous when exposed to intermittent radiation.

The radiation is supplied from incandescent lime, and is focused by a concave reflector. In the path of the rays is a revolving wheel provided with projecting teeth. When a tooth intervenes, the radiation is stopped; but in the interval between the teeth the radiation passes through, and falls upon any object held at the focus. The object in this case is a small glass bulb containing a few drops of ether, and communicating with the ear by a rubber tube. Under the operation of the intermittent radiation the ether vapor expands and contracts; in other words a vibration is established, and a sound is heard by the observer. But if the vapor were absolutely diathermanous, no sound would be heard.

I have repeated the experiment of Tyndall which allowed him to distinguish between the behavior of ordinary air and dry air. If, dispensing with ether, we fill the bulb with air in the ordinary moist state, a sound is heard with perfect distinctness, but if we drop in a little sulphuric acid, so as to dry the air, the sound disappears.

According to the law of exchanges, absorption is connected with radiation; so that while hydrogen or oxygen do not radiate, from ammonia we might expect to get considerable radiation. In the following experiment I aim at showing that the radiation of hot coal gas exceeds the radiation of equally hot air.

The face of the thermopile, protected by screens from the ball itself, is exposed to the radiation from the heated air which rises from a hot copper ball. The effect is manifested by the light reflected from a galvanometer mirror. When we replace the air by a stream of coal gas, the galvanometer indicates an augmentation of heat, so that we have before us a demonstration that coal gas when heated does radiate more than equally hot air, from which we conclude that it will exercise more absorption than air.

I come now to the second division of my subject, that relating to sound. Tyndall, as you know, wrote a book on sound, founded on lectures delivered in this place. Many interesting and original discoveries are there embodied. One that I have been especially interested in myself is on the subject of sensitive flames. Professor Leconte in America made the first observations at an amateur concert, but it was Tyndall who introduced the remarkable high pressure flame now before you. It issues from a pinhole burner, and the sensitiveness is entirely a question of the pressure at which the gas is supplied. Tyndall describes the phenomenon by saying that the flame under the influence of a high pressure is like something on the edge of a precipice. If left alone, it will maintain itself; but under the slightest touch it will be pushed over. The gas at high pressure will, if undisturbed, burn steadily and erect, but if a hiss is made in its neighborhood it becomes at once unsteady, and ducks down. A very high sound is necessary. Even a whistle, as you see, does not act. Smooth, pure sounds are practically without effect unless of very high pitch.

I will illustrate the importance of the flame as a means of investigation by an experiment in the diffraction of sound. I have here a source of sound, but of pitch so high as to be inaudible. The waves impinge perpendicularly upon a circular disk of plate glass. Behind the disk there is a sound shadow, and you might expect that the shadow would be most complete at the center. But this is not so. When the burner occupies this position the flame flares; but when by a slight motion of the disk the position of the flame is made eccentric, the existence of the shadow is manifested by the recovery of the flame. At the center the intensity of sound is the same as if no obstacle were interposed.

The optical analogue of the above experiment was made at the suggestion of Poisson, who had deduced the result theoretically, but considered it so unlikely that he regarded it as an objection to the undulatory theory of light. Now, I need hardly say, it is regarded as a beautiful confirmation.

It is of importance to prove that the flame is not of the essence of the matter, that there is no need to have a flame, or to ignite it at the burner. Thus, it is quite possible to have a jet of gas so arranged that ignition does not occur until the jet has lost its sensitiveness. The sensitive part is that quite close to the nozzle, and the flame is only an indicator. But it is not necessary to have any kind of flame at all. Tyndall made observations on smoke jets, showing that a jet of air can be made sensitive to sound. The difficulty is to see it, and to operate successfully upon it; because, as Tyn-

* Cf. Trouton, in *Nature*, vol. 39, p. 393; and many other optical experiments by Mr. Trouton, vol. 40, p. 398.

† Lecture before the Royal Institution, March 16, 1894.

dall soon found, a smoke jet is much more difficult to deal with than flames, and is sensitive to much greater sounds. I doubt whether I am wise in trying to exhibit smoke jets to an audience, but I have a special means of projection by which I ought at least to succeed in making them visible. It consists in a device by which the main part of the light from the lamp is stopped at the image of the arc, so that the only light which can reach the screen is light which by diffusion has been diverted out of its course. Thus we shall get an exhibition of a jet of smoke upon the screen, showing bright on a dark ground. The jet issues near the mouth of a resonator of pitch 256. When undisturbed it pursues a straight course, and remains cylindrical. But if a fork of suitable pitch be sounded in the neighborhood, the jet spreads out into a sort of fan, or even bifurcates, as you see upon the screen. The real motion of the jet cannot of course be ascertained by mere inspection. It consists in a continuously increasing sinuosity, leading after a while to complete disruption. If two forks slightly out of unison are sounded together, the jet expands and re-collects itself, synchronously with the audible beats. I should say that my jet is a very coarse imitation of Tyndall's. The nozzle that I am using is much too large. With a proper nozzle, and in a perfectly undisturbed atmosphere—undisturbed not only by sounds, but free from all draughts—the sensitiveness is wonderful. The slightest noise is seen to act instantly and to bring the jet down to a fraction of its former height.

Another important part of Tyndall's work on sound was carried out as adviser of the Trinity House. When in thick weather the ordinary lights fail, an attempt is made to replace them with sound signals. These are found to vary much in their action, sometimes being heard to a very great distance and at other times failing to make themselves audible even at a moderate distance. Two explanations have been suggested, depending upon acoustic refraction and acoustic reflection.

Under the influence of variations of temperature refraction occurs in the atmosphere. For example, sound travels more quickly in warm than in cold air. If, as often happens, it is colder above, the upper part of the sound wave tends to lag behind, and the wave is liable to be tilted upward, and so to be carried over the head of the would-be observer on the surface of the ground. This explanation of acoustic refraction by variation of temperature was given by Prof. Osborne Reynolds. As Sir G. Stokes showed, refraction is also caused by wind. The difference between refraction by wind and by temperature variations is that in one case everything turns upon the direction in which the sound is going, while in the second case this consideration is immaterial. The sound is heard by an observer down wind, and not so well by an observer up wind. The explanation by refraction of the frequent failure of sound signals was that adopted by Prof. Henry in America, a distinguished worker upon this subject. Tyndall's investigations, however, led him to favor another explanation. His view was that sound was actually reflected by atmospheric irregularities. He observed, what appears to be amply sufficient to establish his case, that prolonged signals from fog sirens give rise to echoes audible after the signal has stopped. This echo was heard from the air over the sea, and lasted in many cases long time, up to 15 seconds. There seems here no alternative but to suppose that reflection must have occurred internally in the atmosphere. In some cases the explanation of the occasional diminished penetration of sound seems to be rather by refraction, and in others by reflection.

Tyndall proved that a single layer of hot air is sufficient to cause reflection, and I propose to repeat his experiment. The source of sound, a toy reed, is placed at one end of one metallic tube, and a sensitive flame at one end of a second. The opposite ends of these tubes are placed near each other, but in a position which does not permit the sound waves issuing from the one to enter the other directly. Accordingly the flame shows no response. If, however, a pane of glass be held suitably, the waves are reflected back and the flame is excited. Tyndall's experiment consists in the demonstration that a flat gas flame is competent to act the part of a reflector. When I hold the gas flame in the proper position, the peripient flame flares; when the flat flame is removed or held at an unsuitable angle, there is almost complete recovery.

It is true that in the atmosphere no such violent transitions of density can occur as are met with in a flame; but, on the other hand, the interruptions may be very numerous, as is indeed rendered probable by the phenomena of stellar scintillation.

The third portion of my subject must be treated very briefly. The guiding idea of much of Tyndall's work on atmospheric particles was the application of an intense illumination to render them evident. Fine particles of mastic, precipitated on admixture of varnish with a large quantity of water, had already been examined by Brucke. Chemically precipitated sulphur is convenient, and allows the influence of size to be watched as the particles grow. But the most interesting observations of Tyndall relate to precipitates in gases caused by the chemical action of the light itself. This may be illustrated by causing the concentrated rays of the electric lamp to pass through a flask containing vapor of peroxide of chlorine. Within a few seconds dense clouds are produced.

When the particles are very small in comparison with the wave length, the laws governing the dispersion of the light are simple. Tyndall pursued the investigation to the case where the particles have grown beyond the limit above indicated, and found that the polarization of the dispersed light was effected in a peculiar and interesting manner.

Atmospheric dust, especially in London, is largely organic. If, following Tyndall, we hold a spirit lamp under the track of the light from the electric lamp, the dark spaces, resulting from the combustion of the dust, have all the appearance of smoke.

In confined and undisturbed spaces the dust settles out. I have here a large flask which has been closed for some days. If I hold it to the lamp, the track of the light, plainly visible before entering and after leaving the flask, is there interrupted. This, it will be evident, is a matter of considerable importance in connection with organic germs.

The question of the spontaneous generation of life occupied Tyndall for several years. He brought to

bear upon it untiring perseverance and refined experimental skill, and his results are those now generally accepted. Guarding himself from too absolute statements as to other times and other conditions, he concluded that under the circumstances of our experiments life is always founded upon life. The putrefaction of vegetable and animal infusions, even when initially sterilized, is to be attributed to the intrusion of organic germs from the atmosphere.

The universal presence of such germs is often regarded as a hypothesis difficult of acceptance. It may be illustrated by an experiment from the inorganic world. I have here, and can project upon the screen, glass pots, each containing a shallow layer of a supersaturated solution of sulphate of soda. Protected by glass covers, they have stood without crystallizing for forty-eight hours. But if I remove the cover, a few seconds or minutes will see the crystallization commence. It has begun, and long needles are invading the field of view. Here it must be understood that, with a few exceptions, the crystalline germ required to start the action must be of the same nature as the dissolved salt; and the conclusion is that small crystals of sulphate of soda are universally present in the atmosphere.

I have now completed my task. With more or less success I have laid before you the substance of some of Tyndall's contributions to knowledge. What I could not hope to recall was the brilliant and often poetic exposition by which his vivid imagination illuminated the dry facts of science. Some reminiscence of this may still be recovered by the reader of his treatises and memoirs; but much survives only as an influence exerted upon the minds of his contemporaries, and manifested in subsequent advances due to his inspiration.

INSTANTANEOUS PHOTOGRAPH OF A KICKING HORSE.

CAPT. J. B. DUMAS, now in Tunis, and who is one of the most remarkable horsemen of our army, sends us what we consider a most wonderful instantaneous photograph, which we reproduce herewith. It represents a horse in the act of kicking. The attitude is real, since it is registered by photography; but what an extraordinary attitude it is! No painter would dare to reproduce it.

The kick represented herewith was obtained with a three and a half year old horse—an Anglo-Syrian-Barbary one, 16 hands high, possessing great talent and

these reliefs in plaster of Paris, metal, India rubber, ebonite, type metal, copper, earthenware, gutta-percha, or even wood; and very numerous applications of the solid pictures thus obtained will suggest themselves to practical men. In supplying such productions, the photographer may give an impetus to the business of the bookbinder, the cabinet maker, the die sinker, the potter, and the embosser of leather or other soft material; besides affording collateral aid to many other industries. The operation of making the gelatine relief being rapid, and its reproduction so simple, it is a wonder this kind of work has not been extensively practiced by photographers.

The method of making the gelatine relief which we shall describe in the first instance is that which we should suggest as the best for general use, and one so easy that any photographic manipulator may hope to make a successful relief after the first trial.

Two pieces of stout plate glass of a convenient size are taken, let us suppose of whole plate size (8½ inches by 6½ inches), and some of the finest "flour emery" or bath brick is mixed with water and placed between them, and the plates are worked over each other until one surface of each is uniformly ground. The plates, now being carefully cleaned, are finally rubbed with soda solution to remove any trace of grease, rinsed, and put on edge to drain.

We now require to set up two leveling stands in the sink of the dark room, and in the event of no regular leveling stands being available, a convenient substitute may be made by blocking up with wedge shaped pieces of metal, or, indeed, with small coins. A spirit level is not absolutely essential, as, if water is poured on the plates, it will be seen when the upper surface is horizontal.

To prepare the plates for the sensitive mixture, they are now well flooded, ground side uppermost, with a stream of warm water, beginning with moderately warm, and finishing with water at about 70° Centigrade, the gradual heating being necessary to avoid fracture of the plates. Before the hot water has dried off, a quantity of the following sensitive mixture is poured on, so as to drive the water well over the edges of the plates:

Gelatine (Nelson's "Opaque" or "Amber" answers well....	18 parts.
Water.....	100 "

Soak the gelatine, melt in a water bath, and add—

Liquid ammonia.....	1 part.
Bichromate of ammonia.....	3 "



A KICKING HORSE. (From an instantaneous photograph.)

a remarkable conformation. His character is restive, and he uses with the greatest energy all the warnings to keep out of the way that his intelligence can suggest to him. Capt. Dunnas had to put him through a course of training. The horse now performs the most varied evolutions in the open field. At first, the animal was given to rearing, and so his master exercised him in kicking. The training that he has undergone permits of obtaining at will the kick represented in the photograph.—*La Nature*.

PHOTOGRAPHIC RELIEFS FOR DECORATIVE OR ORNAMENTAL USE.

The beautiful modeling of a lead mould, such as is used in printing Woodburytypes, is very suggestive of a variety of decorative uses for the photographic relief; and in the course of a few short articles we propose to give instructions in some methods of making such photographic relief pictures as may serve for ornament or decoration, and it may be mentioned that the methods of making these are very easy—much easier than the making of an ordinary Woodburytype mould.

It is well known that a gelatine film which contains any soluble bichromate becomes so altered by exposure to light as to lose its property of swelling in water. If, then, a film of bichromatized gelatine is exposed under a negative until the darkening produced by the action of light has proceeded so far as to impress every gradation of the picture thereon, a device in various tints of brown on a light yellow ground is obtained, but up to this point the surface of the film remains uniform; that is to say, no part stands out in relief. Let the film—which, by the bye, may either be soaked or attached to a glass plate for support—be now soaked in cold water. The unexposed parts immediately begin to swell, while those which were freely exposed refuse to swell, and those portions which received an intermediate degree of exposure swell to a proportionate extent. In this way there is formed a most delicately modeled and beautiful relief, which faithfully represents all details and gradations of the original negative. The height of the relief depends on the thickness of the gelatinous film, the degree of exposure, the extent to which the film has been soaked, and other circumstances; but it is easy to obtain a relief of the tenth of an inch in ordinary cases. We can readily reproduce

Stir till the bichromate is dissolved, allow the mixture to remain at rest in the water bath till most of the bubbles have risen to the surface, and pour carefully through a piece of muslin (not too fine) stretched over the top of a warmed beaker or jar.

Before leaving the gelatinous mixture to set on the leveled plates, it is important to see that no veins or streams of water remain—a matter which can be insured, if care be taken to allow an even flow from the center to the edges; but any plates where the water may seem to lodge can be readily dealt with by drawing the mixture over with a strip of paper, and, if necessary, pouring on a little more of the gelatinous preparation.

All is now left in position till the gelatine has set, when the plates are put in a warmish place for the film to dry. A gelatine which sets with an uneven or pitted surface—like the "Gold Label" gelatine of Coignet—is unsuitable for our present purpose. As regards the thickness of the film to remain on the plate, it may be mentioned that the colder the plate and the mixture, so much the more will be retained on the glass, and so much thicker will be the film. Before the plates are dry, it is convenient to scrape any gelatine from the backs and wipe them clean, as any lumps may cause fracture in the printing frame. Exposure may be under a negative or a positive, according to the direction in which the relief is to be taken; and it should be continued until the details in the more opaque parts are visible from the back of the plate by the browning of the bichromated gelatine.

The plate is now soaked in cold water until the unexposed parts of the gelatine have swollen sufficiently to give the amount of relief required, and now we proceed to make the plaster cast. A little oil is well dabbed on the face of the relief, and when the excess has been wiped off, strips of wood about an inch high are placed round the plate, and plaster of Paris, mixed with water to the consistency of a thickish cream, is poured into the mould. In order to remove any air bubbles from the face of the relief, a broad camel's hair brush is passed through the liquid plaster and worked to and fro a few times over the gelatine. The plaster being thoroughly set, the border is removed, and the edge of a thin-bladed knife is just introduced along one of the sides between the plate and the plaster. Under these circumstances, a strain will be put upon the plaster

east which will cause it to separate before long from the gelatine. It is well not to hasten the process of separation by the application of any force besides the slight strain set up by the knife blade, but repeated moistening of the back of the plaster cast generally facilitates matters. At any rate, if the whole is left overnight, it will generally be found in the morning that the separation has taken place.

A plaster cast having been made, mouldings in other materials can readily be obtained.—*Photo. Review.*

AMERICAN "TRIPOLL."

By E. O. HOVEY.

TRIPOLI is a term which was originally applied to an infusorial earth, resembling clay or chalk in appearance, coming from the country of the same name in Northern Africa. It crumbles or powders easily between the fingers, is a little gritty to the teeth and scratches glass when rubbed on it. This earth consists almost entirely of silica in the opal or soluble state, and is made up mainly of the siliceous skeletons of the minute animal organisms known as polycystines or radiolarians and of the equally minute plants called diatoms. Similar deposits, frequently of great thickness, occur in many other parts of the world, notably in Barbadoes, Sicily, Calabria, Greece and the Nicobar Islands. The well known "Barbadoes earth" consists mostly of these siliceous skeletons, but contains, besides, a variable proportion of the calcareous shells of foraminifera. This deposit rises to heights of more than 1,000 feet above the level of the sea, while that of the Nicobar Islands reaches an elevation of about 2,000 feet. According to Haeckel, the eminent German naturalist, there are not less than four hundred and there may be more than five hundred species of polycystines in the Barbadoes earth, very many of which are to-day extant and unchanged in the radiolarian ooze of

A well sunk in the northern part of the property gave the following section :

Earth, from the surface.....	0 - 4 ft.
"Tripoli".....	4 - 20 "
Stiff red clay.....	20 - 21½ "
Mixed chert, clay and ocher.....	21½ - 40 "
Cherty limestone.....	40 - 93 "
Cherty limestone, bearing galenite.....	93 - 103 "
Limestone.....	103 - 128 "
"bearing galenite and sphalerite.....	128 - 136 "
Soft magnesian limestone.....	136 - 173 "

The drill was lost in this soft rock at about 173 feet. The first 58 feet of the well was sunk by digging, the remainder by using a six-inch plunger drill.

Not only is the bed of tripoli everywhere underlain by the extremely thin stratum of very stiff red clay, but it is traversed in every direction by seams 1 to 2 inches thick of the same substance. These seams and other joints divide the rock into masses which vary in size up to 30 inches or more in diameter. In color the material varies from an almost pure white, through a cream tint, to a delicate rose, depending, probably, on a difference in the small amount of iron present.

The rock is very even in texture, and is so minutely porous that it forms a most excellent natural filter. For this purpose it is shaped into disks and cylinders for use where gravity alone is to be depended on for forcing the water through the filters, and into thick walled tubes for use under pressure. The disks in actual use range from 4 inches to 20 inches in diameter, and the cylinders and tubes are from 2 inches by 3 inches to 12 inches by 20 inches in dimensions. Even larger sizes than these could be obtained, if desired. The filters are very simple in operation, as they retain on the surface all the impurities of the water, and are cleaned by merely brushing them. They are coming

"Silica soluble in a 10 per cent. solution of caustic soda, on boiling three hours, equals 728 per cent."

The credit of developing this industry is due to Mr. T. T. Lusecombe, of Carthage, Mo., who is president of the American Tripoli Co. The quarries were first opened in 1872, but the great growth of the business has been within a very few years. The company received a medal and diploma award at the World's Fair, Chicago.

LARD.

By H. W. WILEY, Chemist to the U. S. Department of Agriculture.

Butcher's Lard.—The small quantities of lard made by butchers are usually "kettle rendered," after the manner practiced by small farmers in making lard for home consumption. Often the scraps are saved up for a considerable length of time by the butchers before rendering, and that is likely to increase the free acid present. This lard is also frequently dark colored and contains a considerable quantity of glue. In New York this lard is known as "New York City Lard."

Compound Lard.—The term refined lard had long been used to designate a lard composed chiefly of cotton oil and stearine. The largest manufacturers of this kind of lard have now abandoned this term and are using the label "lard compound" instead. This is but just to the consumers of this article, who are likely to be misled by the term refined lard. The prime steam lard in a state of fusion, the stearine also in a liquid condition, and the refined cotton oil are measured in the proportions to be used and placed in a tank at a temperature of 130 deg. to 160 deg. F.

In this tank the ingredients are thoroughly mixed by means of paddles operated by machinery. After mixing, the compound lard passes at once to artificial coolers, where it is chilled as soon as possible. It is then run directly into small tin cans or large packages and prepared for market.

PHYSICAL PROPERTIES OF PURE LARD.

(The degrees of temperature referred to herein are Centigrade.)

Specific Gravity.—The specific gravity of a pure lard varies rapidly with the temperature. It is not convenient to take the specific gravity of a lard at a lower temperature than 35 deg. or 40 deg., inasmuch as below that temperature solidification is apt to begin. The specific gravity, therefore, is usually taken at 35 deg. or 40 deg., or at the temperature of boiling water, viz., 100 deg. At 40 deg. the specific gravity of pure lard is about 0.890, and at 100 deg. about 0.860 referred to water at 4 deg. The specific gravity of pure lard does not differ greatly from that of many of the substances used in adulterating it, but it is distinctly lower than the cotton oil, and is of great distinctive value in analysis.

Melting Point.—The melting point of a pure lard is a physical characteristic of great value. The melting point of the fat of the swine varies with the part of the body from which it is taken. The fat from the foot of the swine appears to have the least melting point, viz., 35 deg. The intestinal fat seems to have the highest, viz., 44 deg. In fat derived from the head of the animal the melting point is found to be 35.5 deg., while kidney fat of the same shows a melting point of 42.5 deg.

In steam lards, representing the lards passed by the Chicago Board of Trade, the melting point for ten samples was found to vary between 29.8 deg. and 43.9 deg. In general it may be said that the melting point of steam lards is about 37 deg., which is the mean of the ten samples examined. In pure lards derived from other localities the melting point was also found to vary. A sample of lard from Deerfoot Farm, Southborough, Mass., was found to have a melting point of 44.9 deg., while a pure lard from Sperry & Barnes, New Haven, Conn., melted at 39 deg. The mean for eighteen samples was 40.7 deg.

While the melting point cannot be taken as a certain indication of the purity of a lard, nevertheless a wide variation from 40 deg. in the melting point of a lard should lead at least to a suspicion of its genuineness, or that it was made from some special part of the animal. Perhaps one reason why the melting point has not been more highly regarded by analysts is because of the unsatisfactory method of determining it; but when it is ascertained by the method used in these investigations, it becomes a characteristic of great value.

Color Reaction.—The coloration produced on pure lard by certain reagents serves as a valuable diagnostic sign in the analysis of lard and its adulterations. Various reagents have been employed for the production of characteristic colors in fats, but of these only two are of essential importance. They are sulphuric and nitric acids. Pure lard when mixed with sulphuric and nitric acids of the proper density, as indicated hereafter, gives only a slight color, which varies from light pink to faint brown.

The variation produced in the colors by pure lards is doubtless due to the presence in various quantities of certain tissues of the animal other than fat. For instance, a variation in the amount of gelatinous substance mechanically entangled with the lard, or of the tissues composing the cells in which the lard was originally contained, would be entirely sufficient to account for the slight differences in color produced by lards of known purity. It might, therefore, be difficult to distinguish accurately between a pure lard containing a considerable amount of other tissues from the animal and one which contains a small amount of adulteration.

The coloration produced, therefore, by the acids named should not be relied upon wholly in distinguishing pure and adulterated lards, but the character of such coloration should be carefully noted in the analyst's book. In the steam lards examined some of the remarks describing the coloration produced are as follows: "Trace of color," "faint pink," "bright pink," "light red," "yellowish," etc. For pure lards of miscellaneous origin some of the descriptions are as follows: "Brownish pink," "trace of yellow," "marked red brown," "no color," "slight coloration," etc.

There are many other hog fat products not used in the manufacture of lard or compound lard, a description of which may prove useful here.



THE AMERICAN TRIPOLI COMPANY'S QUARRY, SENECA, MO.

the deep Pacific Ocean." In Bohemia there is a celebrated deposit of tripoli ("Polar-schiefer"), largely used as a polishing powder, which is composed almost entirely, if not entirely, of the siliceous framework of diatoms. In the United States there are great deposits of diatomaceous earth near Richmond, Va., and Monterey, Cal., of which the former is about thirty miles from north to south across the State, while the latter exceeds fifty feet in thickness and is of unknown extent. All the beds noted above are of Tertiary age.

Tripoli is used very extensively in the form of powder as an abrasive, and forms the base for many polishing pastes and other similar preparations. The extreme fineness of the natural grain, combined with the hardness of the individual particles, composed as they are of silica, gives this substance its advantages for this purpose. It is also largely employed in mixing with nitro-glycerine in the manufacture of dynamite.

Within a comparatively few years there has developed at Seneca, in the extreme southwestern corner of Missouri, a large business in the quarrying and manufacture of a rock which is called "tripoli" for the want of a better term, and because the material in some respects resembles what has so long gone by that name. This rock appears to have been derived from the flint of the country rock, which is a cherty lower carboniferous limestone, by some process of decomposition which has left behind a bed of very fine grained, rather soft, porous material, which has considerable strength when cut into disks and other forms. This particular deposit is known to underlie between eighty and one hundred acres of land as a rude ellipse, with its longest diameter approximately north and south. Numerous prospect holes show that the bed is from 2 to 4 feet below the surface of the ground, and that it varies from 10 to 25 feet in thickness, with an average of about 15 feet. The main quarry of the company working these beds at present shows a section 15 feet thick.

into general use rapidly on account of their efficiency, cheapness and durability. On account of the great absorptive power of the rock, blotting pads have been made from it. These work excellently, but are rather dusty in use. Last year (1893), the American Tripoli Co., which owns and operates this deposit, put on the market more than 20,000 disks, cylinders and blotters. These articles are patented.

A second and fully as important a branch of this industry is crushing the rock and grinding it into flour for use in polishing all kinds of metals, horn, shell, etc. The company grinds the rock in a common mill between burr stones, and sifts it through two bolts of 70 and 120 mesh, similar to those used for bolting wheat flour. Last year the company sold upward of 20,000,000 lb. of this ground and bolted tripoli flour.

A portion was scraped off from a crude piece of the rock and mounted for the microscope. Examination with powers magnifying up to 450 diameters failed to show any remains of the skeletons of radiolarians or diatoms. The particles were extremely minute, by far the most of them being not over 0.01 mm. (= 0.0004 inch) in diameter, though an occasional grain measured 0.03 mm. across, and one was 0.05 mm. through. The particles are doubly refracting and are probably chaledony, while the infusorial tripoli consists of opaline silica.

The following analysis was furnished the company by W. H. Seaman, professor of chemistry in the Missouri School of Mines, Rolla :

Silica (Si O ₂).....	98.100
Alumina (Al ₂ O ₃).....	0.240
Iron oxide (Fe ₂ O ₃ and FeO).....	0.270
Lime (Ca O).....	0.184
Soda (Na ₂ O).....	0.230
Water (ignition).....	1.160
Organic matter.....	0.008
	100.192

ing" petals fastened to toothpicks, as a groundwork; and upon that an elaborately arranged variety of flowers, short-stemmed or wired to toothpicks, disposed according to certain set rules, with very little margin for the artistic taste of the constructor. Such ghastly things are still to be seen at funerals, but even there are going out of fashion.

Then the taste for loose flowers sprang up. Boston claims the honor of leading in that reformation of taste, and perhaps deserves it. It was one which had a directly educational effect. People generally for the first time learned to appreciate the loveliness in flowers, seeing them under such natural conditions, and became critical respecting their niceties of form, tint, size, natural foliage and stem. Certain flowers that had been much in vogue could no longer find acceptance at any price; camellias, for instance, which once were very fashionable and commanded a dollar each in the winter season—equivalent then to double as much now—had no stems at all, and needed to be "stemmed" or "wired," which was quite enough to drive them out of the market entirely. Unfortunate florists who had houses full of the costly camellia japonica trees were ruined. It was a pity, for some of the varieties, formal as they were, like carved ivory, were really beautiful, and one never sees them now that it no longer "pays" to grow them.

In the improved order of things, upon no class of flowers did the newly appreciative public become more critical than in its regard for roses. They must have perfectly graceful forms, pure and brilliant colors, imposing size, exquisite perfume, ample and superb foliage, long stems sufficiently strong to bear them proudly erect, and, withal, reasonable durability. One deficient in any of these qualifications was valued below its real merit. The matchless big golden buds of the Marechal Niel and the slender, elegant snowy buds of the Nipheta went out of favor together almost solely because they had weak, drooping stems. The Perle de Jardin has taken the place of the former, but is only better in having a stiffer stem. The Kaiserin Augusta Victoria and Bride, which have supplanted the Nipheta, are, however, finer flowers, the first named much larger, with exquisite curves in its half-opened petals and a creamy tinge to its whiteness that must be admired.

ROSE CULTURE ON SCIENTIFIC LINES.

To produce roses when nature could not, and to do so with the uniform certainty requisite as a commercial basis, and to go yet further and produce finer roses than unassisted nature could—roses lacking in none of those seven necessary points of perfection—was the problem our florists were called upon to solve. How it has been worked out can in nowise be better shown than in a review of the means and methods of the most perfect rose-growing establishment in the world, that of the F. R. Pierson Co., at Scarborough, five miles from Tarrytown, where the extensive general greenhouses of the corporation are located.

Their seven rose-growing houses here, each 304 feet long by 20 feet wide, with two propagating houses and a central connecting corridor, cover two acres of ground, and are devoted entirely to producing roses for the New York market. No other culture is in any degree allowed to intrude here, except that the propagating houses, when not in their legitimate employment of getting up new rose stock for the benches, are utilized temporarily as adjuncts for the over-crowded Tarrytown houses in bringing on a certain range of perennials for the general plant trade. Even this, however, is only done cautiously, tentatively and under the pressure of extraordinary business demand, for experience has demonstrated that the fine roses are jealous beauties, impatient of the presence of even possible rivals. Each has a clearly marked individuality, and will abate nothing of its absolute requirements as a concession to the different wants or needs of any other plant. Hence it is that such a very exclusive and exacting rose as M. Teor must have a house entirely devoted to itself. Put any other with it and one, or probably both, will inevitably suffer, however great the care exercised in endeavors to reconcile the conditions demanded by each with the other, and however slight the differences between their requirements apparently are. Sometimes two roses of more accommodating disposition may flourish as close neighbors, but hardly ever will three be found capable of forming a happy family, in which all will do equally well. This explains why even the most skillful amateurs, whose greenhouse space is limited, so seldom meet with success in trying to cultivate several varieties of roses, or roses and other flowers, in the same house. Mr. Pierson has long got beyond making any such mistakes.

The seven parallel ranges of "three-quarter span" structures, each 304 feet long, run east and west, and are placed 20 feet apart, so that one may not cast even the least shade upon another in winter. A central corridor, 10 feet wide, with benches on each side of a four foot passageway, connects them, and in a capacious brick tunnel under its floor run the great steam mains and returns, by which heat is supplied from the three great boiler rooms sunk deep under ground and out of sight. On the north sides of two of the structures are the propagating houses, 10 feet wide, which are practically the quarter spans absent from the others. The whole arrangement is such that new ranges of houses may be added on at will, very conveniently, and without even momentary interference with the service of the present plant. And, with like ease, more propagating space may be added to meet growing requirements. The height of the north wall of each house, from ground to glass, is 8 feet 6 inches, of the south wall 2 feet 4 inches boarding, and 2 feet 8 inches side sash above that to the eaves. From the ground to the ridge is 13 feet 2 inches, which gives to the southern slope of roof a pitch of 30 degrees and to the northern 37 $\frac{1}{2}$ degrees. The ends are all glass, iron and steel. The sides, where they are not glass, are of two thicknesses of lumber, with resin-sized paper between. The panes of glass used are 16 by 24 inches, double thick. Those in the first four houses erected are French, but on the three of the later construction American glass is used, it being of superior quality since natural gas has been employed in its manufacture. The rafters are of steel, one inch thick and three inches wide, bedded in concrete foundations, bent at the plate, joined at the

ridge by cast iron brackets, and are 8 feet apart. The purlins, connecting the rafters and supporting the sashbars, are angle irons 1 $\frac{1}{2}$ by 2 inches, located over the walks, so that no drip from condensation of moisture on the glass may fall upon the plants. Cypress sashbars 1 by 1 $\frac{1}{2}$ inches, rabbeted for the glass and supplied with drip grooves to carry away condensed moisture, are employed, and the glass is bedded in putty, lapped and held in place by shoe nails. All the wood and metal parts of the houses are painted a brilliant white, so as to increase by reflection the light which floods the interiors, until one can scarcely realize that there are even thready lines of shade from the opaque portions of the roof. The dying philosopher whose last words were a call for "Light! More light!" expressed the sentiments of the practical florist whose great anxiety, especially if he is growing roses, is to invent new ways for increasing, by even the least perceptible degree, his supply of that necessary element in the dreaded dark days of December and January. These seven rose houses mark steps in the evolution accomplished by American inventive genius toward attainment of perfection in this particular. The first four, erected in 1890, were a great advance upon any preceding them, owing to their substitution of light and strong forms of steel and iron for the clumsy shade-throwing wood or hardly less objectionable metal constructions formerly employed. But in the three since built, notably in the latest, which is not yet five months old, improvement has gone much further on an important line to which Paul Pierson—the brother in practical charge of the greenhouses—gave his attention. An eyesore and grievance to florists has always been the bulky mass made by the sashbars facing and eaves along the front of the house, exactly at the point where its heavy shadow was most injurious in winter, when the sun was low and light scarce. All this Mr. Paul Pierson saw a way to get rid of, but the constructors, seemingly afraid of too radical progress all at once, would only consent to guarantee the strength of the structure with partial adoption of his ideas. As they compromised, all the woodwork along the front eaves is done away with; the perpendicular glass of the front butts up tight against the glass of the sloping roof, and the latter projects sufficiently far to carry drip well beyond the wall. Only a light purlin of 1 $\frac{1}{2}$ inch angle iron is retained to hold the sashbar and supposedly strengthen the structure at this point. But even this Mr. Pierson deems unnecessary, and he has assumed the responsibility of having two sections of the newest house built without that purlin, so that from the low solid wall up to the ridge there is nothing but the absolutely necessary sashbars and minimized metal supports to cast even a thin line of shade. His new way seems to have all the strength that is required, and the increase of light, even by the removal of that small angle iron, is observable.

MAKING AN ARTIFICIAL CLIMATE.

Steam heat is used entirely, because it gives more prompt and perfect control of conditions than is possible when hot water heating is resorted to. The supply main is a five inch pipe, and the return a three inch, hidden out of sight under the corridor floor. Connected with these, in each house, is a simple but perfect double system of piping, beneath the benches, by which a man may in a few seconds turn on the steam for an entire house, or turn it off, or change it from smaller pipes to larger ones, or *vice versa*, all by manipulation of valves at the center of the range; yet all a visitor sees of the elaborate provision for such perfect regulation of temperature—unless he chooses to stoop down and look for it—are the standing pipes carrying the valves, beside the central walk. Temperature is as important a consideration as light in the growing of fine roses; excessive moisture or rawness of atmosphere as much to be dreaded as all the bugs and worms the amateur floriculturist has ever heard of. Even in midsummer the fires under the boilers are never allowed to die out, and there are hardly four weeks of the hottest weather in which steam is not turned on some part of a day or night. Whenever the temperature outside falls to 55 degrees the valves are opened. Even if it only touches 65 degrees, but with much moisture in the atmosphere and a raw wind setting from the east, the steam is in immediate requisition. A dew must never be allowed to form in the houses, for dew is death to roses, producing upon them "black spot," which is a sort of mildew. In the propagating houses, close boarding extends down from the benches to within about fourteen inches of the floor, to keep in much of the heat of the steam pipes, which it surrounds, under the benches. By this device the "bottom heat" applied to the roots of the plants is kept about ten degrees above that of the upper air, in which they spread their leaves. In the rose-growing houses, however, there is little perceptible difference between above and below the benches, and efforts are made to have the temperature in every part of each house exactly the same, and precisely that conducive to the best development of the particular variety of roses in the house. The coal consumption of these seven greenhouses averages a little over 500 tons per annum.

In the propagating houses the benches are constructed of slate, the best material here, since they are required to support a mass of damp, warm sand, which does not need drainage and must receive the heat from below readily and retain it well. In the older growing houses the benches are of yellow pine, which is annually saturated with crude petroleum to preserve it from decay. But in the latest house another of Mr. Pierson's notably ingenious improvements is the substitution of bricks for wood. They are laid half an inch apart, on strong angle iron crop bearers and bottom bars, locked together and bolted to the rafters. Perfect drainage is afforded by the porosity of the bricks and the spaces between them; they are practically indestructible, and though their weight compels the employment of stronger iron supports, that added cost is balanced by their cheapness. A brick flooring altogether is just about as expensive as one of yellow pine, and much less costly than one of slate, as bricks cost only about three cents per square foot and slate eight cents. There are in the older houses four benches—two carrying four rows of plants each, one with three rows, and one of two rows—running the full length of each house, at such graduated heights as will bring

the plants, allowing them space for full development, as close as possible to the glass. The new houses are benched as shown in the accompanying cross sectional view. As the plants are set about fourteen inches apart, there will be very close to 3,241 in each house, or 23,387 in the seven. The benches are covered with earth, which is five inches deep when filled in, but settles down to four inches in a short time.

CULTURE THAT REQUIRES CARE.

The amateur rose grower who has seen with impatience how slowly the rose bushes in his garden become large, and beheld with disgust the "stout three-year old" plants shipped to him on his order by some dealer, would view with amazement the culture attained here, and thenceforth deem nature but a "prentice hand" in the business. But, primarily, it must be understood that the popular idea of "forcing" roses for winter blooming—*i. e.*, that they are impelled to unnatural productiveness by excessive nutrition, watering and heat—is all wrong. The rose has a will of its own, and will endure no such injurious nonsense. Abundant rich food, of just the kind suited to its taste, must be given, but water it too much and you will have "black spot" or "bull head" buds; and give it only five degrees too much heat, to hurry a lot of bloom into unnatural development that you may take advantage of the Christmas market, and all the rest of the season you will have leisure for repentance over a ruined and worthless plant. Once injured, it never recovers. Success is only attainable by keeping the plants constantly in the highest condition of health, from the time they are tiny cuttings only until they are discarded from the benches. Let us see how this is done.

In January and February cuttings—each about three inches long—are made from suitable healthy wood of the old bushes on the benches. These are stuck in damp sand, coarse and sharp, on the propagating house benches, where they have a north light, bottom heat of about 65 degrees and top heat of 55 degrees. In a month they have plenty of roots and are then put in thumb pots (2 $\frac{1}{2}$ inches in diameter) in fine sifted soil, very rich with cow manure and bone meal. The little pots stand on the damp sand, absorbing sufficient moisture from it, and in another month are full of roots and the plants are large enough to be transferred to 3 $\frac{1}{2}$ inch pots. These, too, they fill with roots in a month or six weeks, when they are ready to take their permanent places on the benches. This they are called upon to do in April, May and the early part of June.

Meanwhile a no less important preparatory work has been going on out of doors. The preceding autumn great hills of compost had been formed, two-thirds sod from well-grown pasture, one-third cow manure, and one hundred pounds of bone meal, finally added to every three cubic yards of that mixture. Two or three times, in winter and early spring, the mass, which has been piled in layers, is cut down in thin slices, turned, thoroughly mixed and repiled. When finally ready for use, it is almost black, full of vegetable fiber, and in coarse lumps, which are, however, very friable.

When a house is to undergo its annual change, doors in its ends are thrown open, and tram cars with flanged wheels, fitted to run on the bench sides, are pushed in. The bushes in place are pulled up, thrown upon the cars, run out and cast upon the waste pile. Then the earth in which they have grown is shoveled and swept into boxes to the last spoonful, loaded on the cars and run out. That it is not yet exhausted, notwithstanding all that has been taken out of it, is conclusively demonstrated by its enrichment of the grass land where it is strewn to promote the growth of more sod for next year's compost heaps. The benches are thoroughly cleaned, iron work painted, wood bottoms oiled, and then the new prepared earth is hauled in and distributed to a depth of five inches over the benches. A tram car carries a half cart load of soil at each trip, and is easily run along by a boy, so that this ingenious arrangement is far more expeditious and economical than the old-fashioned way of using wheelbarrows for this laborious work. This soil is in lumps and no effort is made to break it up fine, except just around the roots of the little plants set fourteen inches apart in it. Already these young bushes are so vigorous that they are putting forth buds quite disproportionate in size and abundance to their size, but their ardor is promptly repressed. These first buds are all plucked off, and a little later the more aspiring branches will be cut off well down toward the root. Then new shoots, thick, strong, vigorous, eager to bear bloom, make haste to spring up from the roots, and these are allowed to grow and fulfill their mission. Thus are produced the thick foliated luxuriant stems, three or four feet long, which support the magnificent "American Beauty" roses, unrivaled in form, color or size, flowers that in their highest perfection and in the midwinter season command in the New York market \$24 per dozen wholesale. Of course, the amount of cutting back and "pinching" to which a plant is subjected is governed not only by the general character of the particular variety of rose under treatment, but by the individual development of each plant. And now here is the amazing thing for amateurs to mentally chew upon. Those little cuttings in ten months become luxuriant, prolific bushes six feet high, filling laterally all the space allowed them, yielding a continuous profusion of bloom. They make all that immense growth and supply a large harvest of flowers out of an individual allowance of earth hardly more than would fill a good sized flower pot. And when they are uprooted and thrown away, it is not because their forces are at all abated, or that premature old age, the penalty of a prematurely ripened youth, even threatens them. They have simply become too large for convenience, and it is an open question whether they have not so far exhausted the soil that it might be insufficient for their requirements a second season, even with further liquid fertilization. To be on the safe side every year, new plants are substituted for them, though the substitution in all the seven houses costs altogether about \$2,500. Then, too, two possibilities of deterioration in value are evaded by the annual system of planting. One is that the plants might be subject to greater detriment from slight atmospheric adversities in their second winter, owing to diminished vitality; the other, that as plants age they often develop a ten-

in the widest sense. To the general public, especially those who have rare holidays, but have the wish to learn and appreciation of all they see, they are both recreation and profit. Forms are brought before them they are never likely to see in the flesh; but the life-like work of the taxidermist places them actually before their delighted eyes. To the student, who goes deeper into the nature of all created things, not enough can be said in praise of such institutions, and it is a shame that any large city should be without them. Yet they are only dead, inanimate forms, however great may be the semblance of life given them.

Here let me say a word in favor of the flower shows. I am glad to see increasing in frequency. Take this orchid show I speak of, for instance. There massed together are plants, living, sentient beings, collected at vast expense of toil and money. They are placed before us in all their tropical beauty, growing as luxuriantly as in their homes in the depths of Brazilian or Sumatran forests.

The true botanist, who has spent midnight oil in poring over scientific works on botany, revels in the sight of these plants of such varied and curious organization, and his eyes at last realize what his brain had conceived before; and I fear many a one longs to use his dissecting scissors to unravel some unlooked-for complications in their singular construction. To the real lover of flowers for their own sake, independently of science, it is a rare treat; and one can quietly contemplate such a wealth of floral loveliness inhaling their fragrance and taking in every feature of the display with intense delight.

Equally in a show of roses and other common flowers, it gives food for thought and pleasure to see art and nature hand in hand. By all means give us as many flower shows as possible, but let the price of admission be within the reach of the slender purse as well as the full one.

FOOTPRINTS OF VERTEBRATES IN THE COAL MEASURES OF KANSAS.

By O. C. MARSH.

THE Museum of Yale University contains a small collection of footprints of much interest, which were found in 1873, in the middle coal measures, near Osage, in southeastern Kansas. This collection is part of a larger series of specimens obtained at the locality by the late Prof. B. F. Mudge, who published a short notice of the discovery, which was subsequently

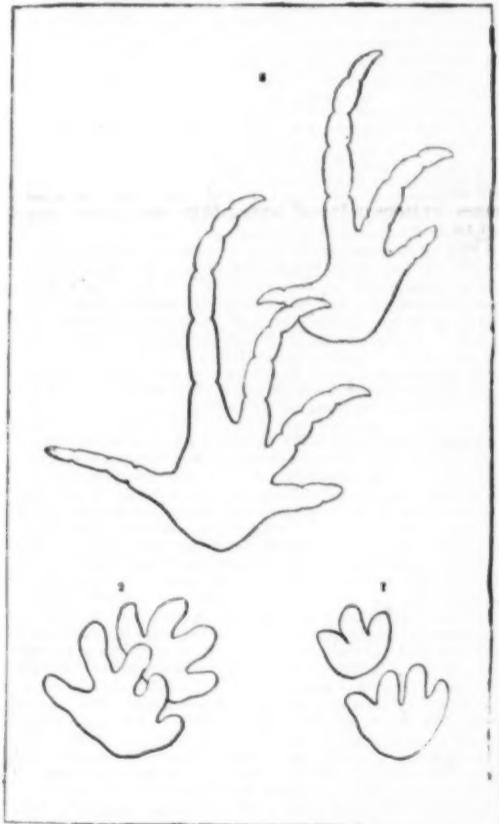


FIG. 1.—Outline of left fore and hind footprints of *Nanopus caudatus*.
FIG. 2.—Outline of left fore and hind footprints of *Limnopus vagus*.
FIG. 3.—Diagram of the left fore and hind footprints of *Dromopus agilis*.

PLATE II.—FOOTPRINTS FROM KANSAS COAL MEASURES.

copied in this *Journal* (vol. vi., p. 228, 1873). The writer examined this entire collection at Manhattan, Kansas, in the autumn of 1873, and secured it for the Yale Museum. The more important specimens were then sent to New Haven, and tracings and notes were taken of the others, which were left to be forwarded later. A careful re-examination of these footprints has been recently made by the writer, and the main results are given in the present article.

The impressions are well preserved in a calcareous shale, which separates readily into thin slabs, each representing a surface of the beach at the time the footprints were made upon it. A few shells in the shale are sufficient to prove that the formation is marine. Trails of annelids, and perhaps of other invertebrates, are seen on some of the surfaces. The footprints of vertebrate animals, however, are of paramount importance, and the large number and variety of these here recorded on a single surface, if they could be rightly interpreted, would form an interesting chapter of land vertebrate life in the carboniferous, about which so little is at present known.

On Plate I., accompanying the present article, five distinct series of footprints are shown, each one-twelfth natural size. All were found on essentially the same surface, and at one locality. The five different animals they represent were thus contemporaries, and indicate a wealth of air-breathing, land vertebrate life at this period hitherto unsuspected.

With these impressions were still others, made either by animals nearly allied or by the same animals under different circumstances. These need not be further noticed in this connection, but they serve to emphasize the diversity of life at this point. The typical series are briefly described below.

Nanopus caudatus, gen. et sp. nov.

The first series represented on Plate I., figure 1, indicates the smallest animal that here left a distinct series of footprints, and the only one in which an imprint made by the tail was preserved. This small quadruped had evidently but three functional toes on the fore feet and four on those behind. The fore feet were considerably smaller than the hind feet. The impressions made by the latter are nearly all separate from the anterior footprints, although at times slightly over-

lapped by the former. The tail impression is a small, elongated, slightly irregular mark, situated between the fore and hind feet, and extending to the right.

Dromopus agilis, gen. et sp. nov.

The third series of footprints shown on Plate I., figure 3, is of special interest, and indicates an animal very distinct from the two already described. On Plate II., figure 3, an outline impression is given, natural size, of one double footprint of this series, made by the fore and hind feet of the left side. This diagram represents the impression of the phalanges sufficiently in detail to indicate their number and general form. A striking feature in the fore and hind feet of this animal was the long, slender digits, terminated by sharp claws. Another point of interest, as recorded in the footprints, is that the animal in walking swung the hind feet outward, and so near the ground that the ends of the longer toes sometimes made trails in the mud, marking accurately the sweep of the foot. This would seem to indicate a comparatively short hind leg, rather than the long, slender one which the footprints themselves naturally suggest.

The animal that made these interesting footprints

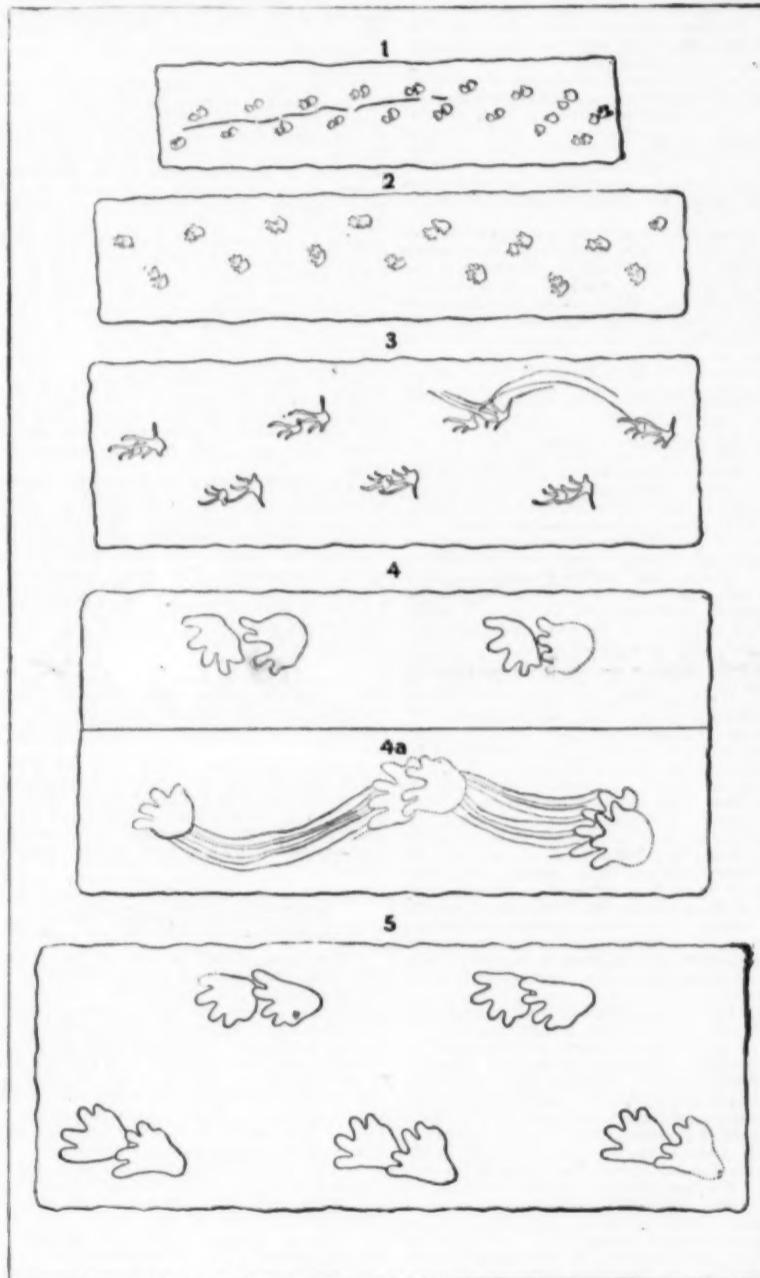


FIG. 1.—Series of footprints of *Nanopus caudatus*, Marsh; showing also, impression made by the tail.
FIG. 2.—Series of footprints of *Limnopus vagus*, Marsh.
FIG. 3.—Series of footprints of *Dromopus agilis*, Marsh; showing trails made by the toes.

PLATE I.—FOOTPRINTS FROM KANSAS COAL MEASURES.
(One-twelfth natural size.)

lapping them. One fore and one hind footprint of this series are represented, natural size, on Plate II., figure 1.

The nature of the animal indicated by these impressions can at present be a matter of conjecture only, but the probabilities are in favor of its reference to the amphibians rather than to the true *reptilia*. As it is evidently distinct from anything hitherto described, the above name is proposed for it.

Limnopus vagus, gen. et sp. nov.

In figure 2, Plate I., a second series of footprints is represented, somewhat larger than those above described, and evidently made by a very different animal. A fore and hind footprint of this series are shown, natural size, in figure 2, Plate II. The front feet had four functional toes, while those behind had five, all well developed. The impressions of the hind feet, as a rule, overlap those of the corresponding fore feet. No indications of a tail can be detected. In length of stride, and in the distance between the footprints of the right and left sides, the present series is proportion-

ally about the same as those above described, although the animals differed much in size. They were probably both amphibians, and may have been nearly allied.

Allopus littoralis, gen. et sp. nov.

Besides the footprints above described, which pertain to animals of comparatively small size, there are several other series in this collection made by very large animals, which were probably all labyrinthodonts. These tracks were made on the same beach, and at about the same time as the small footprints, but not all under the same circumstances. The largest animal thus represented appears to have walked on one part of the beach that was quite firm, leaving very shallow footprints, and again to have traversed another part, quite near the first, but slightly covered with water, or at all events so soft that deep impressions were made by the feet, while the toes of the hind feet also left deep trails as they swung outward at each step. On Plate I., figures 4 and 4a, these two kinds of footprints are represented. They show the stride of the animal, and, as put together, also denote the width be-

tween the footprints of the two sides, so that the series can be compared with the others on the same plate.

These tracks show that the animal had five toes in the fore feet and four behind. The hind feet show a distinct impression of a sole. There is no imprint of a tail, even where the mud appears to have been deep.

Baropus latus, gen. et sp. nov.

The most abundant of the large footprints are represented by several series, which are remarkably uniform in stride and in width between the right and left rows. One of these series is represented on Plate I., figure 5, and this is typical of the others. The animal that made these footprints evidently had four functional toes in front and the same number behind. On the inner side of each foot, however, there was a projection, which, in the hind feet, was quite prominent and characteristic, but can hardly be interpreted as the imprint of the first digit. Nearly all these footprints show a distinct impression of a sole. This is usually faint in the tracks of the fore feet, but strongly marked in those behind.

It is hardly necessary at this time to attempt a detailed comparison of the footprints above described with those already on record, but the writer hopes to do this later. The present specimens all have well marked characters, and, being from a single horizon and locality, have a value of their own as throwing light on the land vertebrate life during the deposition of the true Coal Measures. If, in themselves, they add but little to what is already known, they at least offer encouragement to investigators in an interesting field not yet systematically explored. The publications of Logan, Lyell, King, Lea, Dawson, and others, have already made known discoveries of importance in this country, and others have been recorded in the Old World.

So far as at present known, land vertebrate life began in the carboniferous age, no footprints or other remains of this kind having been detected below the subcarboniferous. That such remains will eventually be found in the Devonian, there can be no reasonable doubt, and perhaps even in the Silurian, if the land surfaces then existing can be explored.—*American Journal of Science*.

ASSYRIAN SCULPTURE AT THE BRITISH MUSEUM

By GEORGE CLINCH

In the midst of the multitudinous diversity of the treasures which enrich the cabinets of the British Museum—the rare editions of books, the unique specimens of antiquity, and the beautiful and justly admired examples of Old World art—one is naturally apt to lose sight of some, at least, of the exhibits which are there arranged for public inspection. It is impossible to ramble through the public galleries without some feeling of bewilderment in the contemplation of so vast a number of objects of importance which have acquired *world-wide* fame.

The Assyrian sculptures, for instance, embracing works of the greatest interest on account of their remote antiquity, their value as art monuments of an ancient and powerful people, and the wonderful circumstances which have attended their origin and history, have never yet been adequately appreciated by the average visitor to the British Museum. This is all the more remarkable in view of the fact that they are of inestimable value on account of the light they throw upon the pages of Biblical and secular history. The colossal sculptures, surrounded by an atmosphere of mystic symbolism, can hardly fail to attract the attention of all beholders. Their gaunt, grim proportions stand out in such a manner as to command the attention of passers-by. But the less imposing slabs of stone, carved with battle scenes and various other illustrations of ancient life, although less remarkable as to size and less impressive in the subjects they portray, are by no means less interesting from an historical standpoint.

So much attention is bestowed nowadays upon the work of men in past ages that it is not necessary to dwell upon the great importance of the study of ancient Assyrian art as a prelude to that of Phenicia and Greece. Sculpture of Assyrian date, or rather that which was executed during the period of Assyria's greatness, presents us with two very remarkable characteristics. In the first place, there do not appear to have been any good examples of sculpture in the round, and, in the second, there was a wonderful richness of design and of exquisitely finished work in the form of bass-reliefs. But this was more the result of the requirements of the architect and the striving for certain desired end than any clear indication of the narrowness of Assyrian art. It may be partly accounted for by the fact that the large buildings of Nineveh, in which we behold the blending of the temple with the royal palace, were constructed largely of brick, and this work was covered by sculptured slabs of stone and colossal statues. This style of building was, doubtless, to some extent an adaptation of a Babylonian model, although carving was employed to a much larger extent in Assyrian than in other architecture. Indeed, it may be safely asserted that in no buildings of any age or country have carved figures borne so large a share in structural art in the palaces and other public buildings as in those of the buried Nineveh. Here, around the walls of the state apartments, were portrayed in bass-relief or colossal statuary, in a manner displaying a high state of artistic development, the doings of the rulers and great men of old. Pictures of the chase, warlike operations, public functions, and religious ceremonies served to illustrate and perpetuate the exploits, the triumphs, and the national history of the once mighty Assyrian empire.

The preservation of these valuable art relics may be said to be chiefly due to the circumstance of their being carvings upon thin slabs of stone. Had large blocks been employed, it is doubtful if they would ever have been brought to European museums, where their historical value can be justly appreciated. It is doubtful, too, in that case, whether they would have escaped destruction by violence or the ravages of time. But it fortunately happened that when the ancient buildings were destroyed these precious relics were safely buried among the debris, and some of them are to this day

almost as fresh and perfect as when they were finished by the sculptors of ancient Nineveh.

A vast amount of pains and skill must have been employed in the construction and ornamentation of the apartments of the sovereign. The royal presence was guarded by colossal forms representing human-headed and winged animals. In these curious compositions it would seem that every feature was intended to typify some attribute of strength, intelligence or other quality. "What more sublime images," inquires Layard, "could have been borrowed from nature by men who sought, unaided by the light of revealed religion, to embody their conception of the wisdom and power of the Supreme Being? They could find no better type of intellect and knowledge than the head of the man, of strength than the body of the lion, of ubiquity than the wings of the bird. These winged, human-headed lions were not idle creations, the off-springs of mere fancy; their meaning was written upon them. They awed and instructed races which flourished three thousand years ago."

The art of sculpture in ancient Assyria appears to have gone through three phases, and its first period may be considered to have begun with the age of Assur-natsir-pal, a monarch who lived between 883 and 858 B. C. Although mainly restricted to carvings in bass-relief, its most striking characteristics were boldness and vigor. It rarely had any background, and perspective would appear to have been almost entirely unknown.

The second period, extending from the foundation of the second Assyrian empire to the reign of Esar-haddon, displays a want of vigor, which, however, is to some extent compensated for by care and accuracy.

The best period of Assyrian sculpture is that of Assur-bani-pal, or Sardanapalus, as he has sometimes been called. The delineation of animals was at this time most admirably true to nature, vegetable forms had lost much of their stiffness, and there were several examples of successful foreshortening; but, curiously enough, the Assyrian artist was rarely, if ever, successful in human portraiture. Speaking generally, there was a return to the freedom of the first period, but without its accompanying rudeness and want of skill. On many accounts the obelisk of Shalmaneser II. (858-823 B. C.) may be considered to claim a foremost place in the collection. It records, by inscriptions and pictorial illustrations, the tribute brought to the Assyrian king by five people. The king, Shalmaneser II., is twice depicted, and near him, in both instances, are the winged circle or globe, the token of the Supreme Deity, and one of the heavenly bodies, the sun or a star.

There are five panels of sculptured figures on each of the four sides of the monument, and above and below them is an inscription 210 lines in length. The animals depicted comprise the elephant, rhinoceros, two-humped camel, wild bull, lion, stag, and various kinds of monkeys. The most important fact about this monument, however, is the valuable confirmation it gives to Biblical history. In the second panel from the top on one side we have a representation of the offering of the tribute of Jehu, King of Israel. The prostrate figure before the Assyrian monarch is supposed to be either King Jehu himself or his ambassador. The inscription relates that Shalmaneser received from Jehu, in the form of tribute, "silver, gold, pitchers of gold, lead scepters for the king's hand and staves."

Another important Biblical monument is the bass-relief representing the siege of Lachish by Sennacherib, as described in 2 Chron. xxxii. The story of the subsequent destruction of the hosts of this King of Assyria is told in the Second Book of Kings, in the prophecies of Isaiah, and in the elegant verses of Byron :

"— the Angel of Death spread his wings on the blast,
And breathed in the face of the foe as he passed;
And the eyes of the sleepers were deadly and chill,
And their hearts but once heaved, and forever grew still."

"The Lion Hunt" is one of the choicest and best preserved examples of the sculpture of the days of Assur-bani-pal. It represents the king, clad in richly ornamented robes, riding on horseback, in the act of slaying a lion. From the knowledge of art displayed in the treatment and composition, the correct and effective delineation of the men and animals, the spirit of the grouping, and its extraordinary preservation, this is probably among the finest specimens of Assyrian art in existence. The curious disposition of the forelegs of the lion indicates the artist's struggle for realism rather than ignorance of anatomy.

As this interesting composition depicts the king engaged in hunting, so the famous "Garden Scene" gives us a vivid picture of what may be called his domestic life in the precincts of his palace. He is represented as reclining upon an elaborately wrought couch, resting, apparently, after warlike or hunting expedition, and surrounded by numerous evidences of luxury and pleasure. The king is sheltered from the sun's heat by an arbor of vines, and his discarded bow, arrows, and spear are placed behind him. His queen is seated in a chair of state opposite, and both are represented as holding drinking cups near the mouth as if about to drink. There is some reason to think that this may be a picture of a festival after a military expedition, from the fact that a man's head, exhibiting a strongly marked Hebrew profile, is hanging from one of the trees in the garden. Some authorities consider this to be the head of Teumman, King of Elam, and, if so, this scene probably represents the banquet in honor of Assur-bani-pal's victory over his enemy.

The figure of the queen is of the highest interest for two reasons. Not merely is this the only known ancient example of an Assyrian lady of high rank represented in a base relief, but it is of particular value from the fact that the details of the costume and personal ornaments have been so carefully delineated as to give a good idea of the fashions of domestic life during what may be properly described as the golden age of the Assyrian empire.

Numerous attendants are shown around the king and queen. Some bring dishes of viands and fruit, others are in the act of dispersing flies by means of what are known as "fly flappers," and others are playing upon musical instruments. These and many other points suggest an appropriate and artistic manner, the luxury and wealth of the court of Assur-bani-pal.

* The trees in this garden scene, although treated in a somewhat formal and conventional manner, show considerable variety of foliage, and were probably intended to typify the range and extent and vegetable wealth of the immense empire which at that time was under Assyrian sway.

Assur-bani-pal was in every sense a great king. His tastes were of a liberal and refined character. He was not merely a warrior and a sportsman, but he was also a great patron of literature and the arts. He built the most magnificent of all the Assyrian palaces, and collected within its walls the finest sculpture which could be produced by native artists. He had a mind in advance of his time. While other kings had been content to leave behind them records of their exploits inscribed on stone tablets and cylinders, he it was who founded the vast collection of clay tablets whereon were inscribed comparative vocabularies and other information of the most valuable kind, including the legends which relate to the creation and the deluge.

It is gratifying to find that popular interest in ancient Assyrian art is to a marked extent being revived. Not long ago some remarkably fine reduced reproductions of some of the more notable examples were exhibited at the Royal Institution of Great Britain, where they met with an appreciative reception. The fact that a lecture room has been opened at the British Museum is a step in the right direction, and another indication of the increasing popularity of this fascinating branch of study.—*The Graphic, London.*

HELEN KELLER.

By KATHARINE D. PARTRIDGE.

ONE of the most surprising and wonderful developments of modern science during the last few years has seemed to be the giving of speech to those who are, in the common parlance, deaf and dumb. The first step toward teaching these unfortunate to speak was the fact that science at last recognized that in nearly every case the organs of speech were perfect and that mechanically there was no reason why the dumb might not speak if they only knew how or if some method of instruction could be devised by which they could be taught to properly use the organs. Recognizing this fact, careful study and a scientific analysis of language has enabled experienced teachers of to-day to actually give intelligent speech to the deaf. When Laura Bridgeman, who was both blind and deaf, was taught to understand fingerings in the manual alphabet, reading, and writing an intelligible hand, it was rightly considered one of the triumphs of this scientific age, but in our own day a step further has been accomplished. In Helen Keller we find a child whose sight and hearing were lost so early an age as to make her quite as unfortunate as one born without either sense. Her attainments, not only in the way of reading the manual alphabet and writing, but in actual speech, and in the still more miraculous art of being able to read from the lips the speech of others by the sense of touch, has made her the wonder of the age. Most of our readers are doubtless familiar with the fact that this child talks and talks very fluently. Her instruction began when she was seven years of age, and was conducted by means of the finger spelling, the child feeling in her own palm the motions of the teacher's hand. About three years ago, Helen, having become much interested in the story of a little Norwegian girl, afflicted like herself, who had learned to communicate by word of mouth, spelled to her teacher the words, "I must speak." She was taken to Miss Sarah Fuller, of the Horace Mann School, in Boston, where deaf mutes are taught to articulate, and received from Miss Fuller eleven lessons on the elements of speech. The child familiarized herself with the relations of the parts used in speech—the tongue, lips, teeth and the hard and soft palate—by feeling with her fingers their position in Miss Fuller's mouth. Miss Fuller then pronounced the short sound of I as, for instance, in the word fill, placing Helen's unoccupied hand upon the larynx at the lowest point where the vibration could be felt. "When I ceased making the sounds," says Miss Fuller, "Helen's fingers flew to her own mouth and throat, and, after arranging her tongue and teeth she uttered the sound so nearly like that I had made, it seemed like an echo of it." She had at this time a very good command of language gained by means of the manual alphabet, and, as she at once applied what she learned in these lessons, she soon began to use speech intelligibly and freely, and now invariably employs it as the medium of communication unless her *cis-a-cis* happens to be a sign-taught deaf mute. Strangers have no difficulty either in making themselves understood, or in understanding her. She reads the lips by placing her fingers over the mouth and upon the throat of the speaker. Before proceeding further, I ought, perhaps, to state that, in the conversation recorded below, the manual alphabet was chiefly, though not solely, used in communication with her. Her replies were always in fluent and distinct speech.

She was asked by a prominent member of the association whose convention at Chicago in the summer had drawn together some two hundred persons interested in the teaching of speech to the deaf, which she would prefer to receive, her sight or her hearing. Her reply was, "Of course I should be happy to receive both, but that can never be and I do not expect it." Upon being pressed for a direct answer to the question she said, "My hearing, for then I should be able to enjoy the voices of my friends, and music; and," she added in her pretty way, "music is so very sweet." "What is your idea of sweetness in that connection?" Quick as thought she responded, "Why, just the same as yours!" The laugh was at the questioner's expense, but he persisted, "I should find it rather difficult to define my idea of sweetness," and she answered, "It is just the same with me." She afterward said that music was pleasant or unpleasant to her according to the difference in vibration. A few evenings later, I had the pleasure of hearing her render a selection upon the piano, and it was then and still is the greatest marvel to me that a child unable either to see the keys which she strikes or to hear the tones which result, can produce "concord of sweet sounds."

When the report of the committee on necrology was presented, some one suggested, after the name of Phillips Brooks had been read, that no one could

speak more feelingly of him than his little friend Helen Keller, who was accordingly invited to the platform. She began, "I shall be very glad to say a few words about my friend, Bishop Brooks, but you must not expect me to say much, for my heart is too full of tears. It seems as if I were sitting beside him now, with my hand in his, and as if he were saying 'Dear child,' he always called me 'Dear child.' 'I am not far from you, but very near in that heavenly country to which I have gone.'" Much more she said very, very touchingly, but I will content myself with reporting these few sentences.

Any one who has had experience in teaching deaf mutes knows how difficult it is to awaken in them any appreciation of a joke. Helen Keller's case is a notable exception to this rule. For nearly an hour one evening she told jokes and asked conundrums (many of which were original), and answered those given her from the audience. The following is one of those which she asked that evening. Whether or not she is its author, I am unable to state, but it is good enough to bear repetition. "Why should not one tell secrets in a vegetable garden?" "But," said the gentleman to whom the question had been put, "I like to tell secrets in a garden." "Yes," she said, "in a flower garden, but I said in a vegetable garden." She was greatly delighted when he "gave it up," and told him it was because the corn had ears, the potatoes had eyes, and the little blade would take a cob and carry the news.

Another wonderful thing is the way in which she recognizes people whom she has once met. I was introduced to her one Sunday afternoon. When we shook hands I wore no ring or bracelet by which it would have been possible for her to distinguish me. Several days after I came up to her and took her hand, and she turned instantly, saying, "Why, Miss Partridge." She was meeting scores of people daily and yet, in all the time I was there, I never knew her to fail to recognize any one who had been introduced to her.

A few days before I left Chicago, the World's Fair management gave her permission to touch any of the exhibits. When she was told of this, her first word was "Incredible!" her next, "How very kind!"

She recited for us on three occasions, the selections being Tennyson's Bugle Song, The Flowers and the Psalm of Life, by Longfellow. Those who saw her then will never, I think, forget it.

Standing on the platform—how much alone in spite of the crowded room, none of us can know—the beautiful soul shining through the beautiful face and the words ringing out with an intensity not to be described, we heard her say:

"Not enjoyment and not sorrow
Is our destined end and way,
But to act that each to-morrow
Find us farther than to-day.

"Lives of great men all remind us
We can make our lives sublime,
And departing leave behind us
Footprints on the sands of time."

And, for some of those who listened, the familiar stanzas have a new and deeper meaning.

Helen Keller is now thirteen years of age. Her home is in Tuscaloosa, Ala., but during the school year she, with her teacher, Miss Sullivan, who has had charge of her education from the beginning, has been at the Perkins Institute for the Blind, in Boston.

THE BAMBOO—WAN-LO'S COMPOSITION.

By ELIZABETH CUMINGS.

A CHINESE boy learns to write by laying a piece of thin paper over a written page and carefully tracing the characters, as we trace pictures on a transparent slate. The Chinese characters do not correspond to our alphabet, but are really mimimutes of pictures long forgotten. There are different ways of making these characters, corresponding to our Roman, italic and script letters, and it takes a good deal of patient practice to make a good writer, or, as the Chinese say, "to hold a flowing pencil."

Wan-Lo had always found his writing lesson tedious and dull, and his tutor had often to exhort him to take more pains. "It is a great mistake to think blots and crooked lines show the writer a genius, with thoughts too big to permit him to attend to little matters," he would say to Wan-Lo. "A gentleman and a scholar should write so that all the world can read." But Wan-Lo, being full of his own boyish business, did not think much about these words till his father's cousin, Hi-Wang, came to Foochow. Wan-Lo's chief desire was to be a great scholar, and to travel about the world as had Hi-Wang. But of the labor that goes before wisdom he had thought little. His grandfather was very rich, but he was also very cautious, and when he said, "I intend to do everything possible for my dear Wan-Lo," he always added, "if he deserves it." When Wan-Lo saw Hi-Wang write, he remembered not only his tutor's words, but his grandfather's condition. It was like watching a bird skimming through the air to look at Hi-Wang's hand going over paper. In spite of himself Wan-Lo wept, thinking how very different were his own performances. But, reflecting that tears would never improve his work with his pencil, he set himself diligently to work. Long before the sun climbed out of the sea he was up and at it; and if his mother had not been very timid about fire, he would have burned out many candles studying at night. But perseverance conquers all things, and at last he could write well enough to tell his thoughts, and then he secretly composed the following sketch about the plant he admired more than any other, the bamboo:

"I do not know much about this wonderful plant, but I know more about it than I do about some other things. That is why I chose it for my subject. Mo-Me, my tutor, says no one talks foolishly who sticks to what he knows. We have a bamboo hedge in our grounds, and nothing could be prettier. I am writing with a bamboo-handled pencil, and I have seen boats with bamboo masts. On the whole, Mo-Me says, the bamboo is one of the most precious possessions of China. Its tapering stalks supply joists for houses, ribs for sails, shafts for spears, tubes and buckets for water, fishing-rods, and the handles and ribs of our

fans; and the great bamboo, split, makes a most excellent roof. In a freshly cut bamboo, so full is it of moisture, flowers can be sent long distances. Middling-sized bamboos make neat bottles. Indeed one can have all sizes of bottles. From the roots of the bamboo are carved children's toys and canes for the aged and infirm, and leaves, sewn upon strings, form a snug rain cloak for the traveler and farmer, while the poor man can use them to thatch his house. Rafts are made of the bamboo, baskets are woven of it, and the stout twisted boat cable and the soft mat are alike woven of it.

"Not only does the wise Chinese write out his heavy given thoughts with a bamboo-handled pencil, but he sits in a bamboo chair, at a bamboo table, and he may rest himself in the heat of the day beneath the shade of bamboos, a bamboo hat upon his head. At dinner he may eat the soft and succulent young shoots of the bamboo stewed with rice, or as pickles, with bamboo chop-sticks, and, untangling the bamboo strings that close the porcelain jar, regale himself with bamboo preserves.

"Boys who are permitted to accompany their songs with bamboo clappers (I never had a pair of these delightful instruments, for my honorable father would not permit me to make such noise). Schoolmasters punish careless or mischievous pupils with the bamboo (I never had to suffer blows: Mo-Me has a kind heart; then, stripes will not make a dull boy clever). The carpenter putting up a bamboo fence or shed uses a bamboo rule. The druggist pours out all his medicines into a bamboo measuring-cup, and he and the merchant use a bamboo abacus to help them add up their accounts. The cook blows his fire with a bamboo bellows, and old gentlemen keep their pet birds in bamboo cages.

"My honorable father once said that silkworms' eggs are sent out of our land of flowers to the people on the edges of the earth in boxes of bamboo; and I have a bow and arrows of bamboo, while I have seen old Fun-Ban, who shaves men in the streets, whetting up his razor on a bamboo strop. There are many other uses for this 'Lord of all the Reeds,' which is too beautiful and useful for a boy like me fully to describe. But when, like our honorable cousin Hi-Wang, I have gone all about the edges of the world in a fire-junk, and have seen all sorts of strange sights and strange people, I ask nothing better than to come back home and sit under the shade of a bamboo veranda, and, when my life shall be accomplished, to ascend the sky from a bamboo bed."

When Mo-Me had read this composition (he read it quite unbeknown to his pupil), he carried it off to Wan-Lo's father, who in his turn carried it to Wan-Lo's mother, and she, being as proud as possible of its cleverness, immediately sent out crimson cards of invitation to her father and mother to come and spend the day.

They came the very next morning. Grandmother had her head wrapped up in a silken scarf for fear of the sun, and grandfather brought his pet parrot along in a bamboo cage, and they were taken directly to see their daughter, who herself read to them the wonderful composition about the bamboo, while they refreshed themselves with tea. Then the grandfather went to the library, where Wan-Lo was studying with Mo-Me. After the greetings, which were ceremonious, for the grandfather was a very aged man, Mo-Me showed the new books in the library.

"Poorly bound," said the old gentleman, testily. "Like everything done now, they show a great falling off in finish. I don't know what the world is coming to. The silk splits, and the filling drops out of the cotton cloth, and the shoes are a shame to the shoemakers. Even the weather has changed. It was never so cold in winter when I was young."

"Did you have splendid times when you were young, venerable grandfather?" asked Wan-Lo, shyly.

"Well, not splendid exactly, but perhaps I did, as you mean the word. The best time I ever had was when I went to Pekin with my blessed father in a mandarin junk. The outlandish invention we call the fire-junk had not then invaded the Yellow Seas as now. Honest wood, rowed by honest men, was good enough for plain people; and, speaking of rowing, you've no idea how difficult it is to row across the Yellow River when the water is high. A man can go through mud and come out whole. I am a proof of it."

"Then you went through the Grand Canal, grandfather?" cried Wan-Lo.

"Certainly," said the old gentleman. "How else? I wasn't a sugar boy to melt with fear; but I can tell you ants ran up and down my back when I journeyed through the place where the canal is twenty or more feet higher than the surrounding country. Men cannot see, nor foresee, all things. Each night when I went to bed I would whisper to myself, 'What if something breaks?' You see I was always cautious, never putting both feet in a puddle at once. But, now I am old, I wish I had seen more of what there is in our own land, and on the edges of it; and it is true as leather that a man cannot behold the world sitting in an armchair."

"Oh, how I would love to go and see things—all China, and the edges of the world!" sighed Wan-Lo to himself.

Just then dinner was announced. Grandfather started up. "I have made up my mind," said he, his pride in Wan-Lo getting the better of him. "You remind me of myself, when the weather was better and I was young. You study and be a good boy. But—well, I have read that composition of yours about the bamboo. You keep right on, and as sure as I now live I will see to it that you have money to go around the world in a fire-junk."

"Like Hi-Wang, venerable grandfather?" exclaimed Wan-Lo, almost beside himself with joy.

"Like Hi-Wang," said the grandfather. "I am a cautious man, but when I promise, I promise."—*The Outlook.*

TYPHOID FEVER—IN MEMORIAM.

ACCORDING to a newspaper report, one of Alleghany's philanthropic select councilmen proposes to present a drinking fountain to that fair city. As all well regulated fountains should have an inscription, the Pittsburg *Medical Review* suggests the following:

"Erected to the memory of one hundred and sixty-one citizens who drank of this water and died of typhoid fever during the year 1893. This water is warranted to be drawn from the Alleghany River at a point where the discharges of eighteen sewers of Pittsburg are mingled with the stream, and each drop contains on an average two hundred bacteria." And adds:

"These eighteen sewers drain an area of seven thousand acres—more than two-thirds of the entire territory of Pittsburg, exclusive of the South Side. Some of them pour their contents into the river a short distance above the influent pipes of the Alleghany water works, while others are situated irregularly for five miles above, so that the entire volume of water must become contaminated by the Pittsburg sewers, not to mention the surface drain from upper Alleghany and the numerous towns along the Alleghany and its tributaries. The discharges from the West Penn Hospital patients find their way into the river at a point that is specially well adapted for transference into the Alleghany reservoir, and as many fever patients are treated there during the summer and fall months, when the stage of the water in the river is usually low, the prevalence of fever and death in Alleghany is to be expected, and the source of the infection is not difficult to trace."

THE LEGAL ASPECTS OF THE DISORDER AT CHICAGO.

By AUSTIN ARBOTT, Dean of the New York University Law School.

THE duty of the government is well described in the oath which we have required our public officers to take.

The President is sworn "to faithfully execute the office of President of the United States, and to the best of his ability to preserve, protect and defend the Constitution of the United States." (U. S. Const., art. 2, sec. 1.) And the Constitution also prescribes that "he shall take care that the laws be faithfully executed" (sec. 3). It also says: "The Constitution, and the laws of the United States which shall be made in pursuance thereof, . . . shall be the supreme law of the land, . . . anything in the Constitution or laws of any State to the contrary notwithstanding." (U. S. Const., art. 6.)

The judges are sworn "to administer justice without respect to persons, and do equal right to the poor and to the rich, and to faithfully and impartially discharge and perform all the duties incumbent on them as such judges, according to the best of their abilities and understanding, agreeably to the Constitution and laws of the United States." (U. S. R. S., sec. 712.)

What is required by the "Constitution and the laws" concerning such controversies?

The Constitution declares as a fundamental element in the organization of the nation, that "Congress shall have power . . . to regulate commerce . . . among the several States; . . . to establish post offices and post roads; . . . to provide for calling forth the militia to execute the laws of the Union, suppress insurrections, and repel invasions; to make rules for the government and regulation of the land and naval forces." (U. S. Const., art. 1, sec. 8.)

By sec. 3,904 of the United States Revised Statutes, post roads are declared to be: All railroads in operation, letter carrier routes, and all waters, canals and roads during the time the mail is carried thereon.

Congress is nothing else than the representative of the people and the States, chosen by them for such purposes because they cannot all assemble and deliberate together, and chosen after free popular discussion of the measures the people at large have desired as necessary for common welfare. Thus chosen for these purposes, Congress has prescribed the following rules for the promotion of the peace and prosperity of the country:

United States Revised Statutes, sec. 3,905: "Any person who shall knowingly and willfully obstruct or retard the passage of the mail, or any . . . carrier carrying the same, shall, for every such offense, be punishable by a fine of not more than \$100."

Id., secs. 5,836-5,440: "If two or more persons in any State or Territory conspire . . . by force to prevent, hinder or delay the execution of any law of the United States . . . each of them shall be punished by a fine of . . . not over \$5,000, or imprisonment . . . not over six years, or both."

Id., sec. 5,298: "Whenever, by reason of unlawful obstructions, combinations, or assemblages of persons . . . it shall become impracticable, in the judgment of the President, to enforce, by the ordinary course of judicial proceedings, the laws of the United States within any State, it shall be lawful for the President . . . to employ such parts of the land and naval forces of the United States as he may deem necessary to enforce the faithful execution of the laws of the United States."

Id., sec. 5,299: "Whenever . . . domestic violence . . . or conspiracies in any State so obstruct or hinder the execution of the laws thereof, and of the United States as to deprive any portion or class of the people of such State of any of the rights, privileges, or immunities or protection named in the Constitution and secured by the laws for the protection of such rights, privileges and immunities, and the constituted authorities of such State are unable to protect or, for any cause, fail to protect such rights, such facts shall be deemed a denial by such State of the equal protection of the laws; and in all such cases, or whenever any such . . . violence . . . or conspiracy opposes or obstructs the laws of the United States or the due execution thereof, or impedes or obstructs the due course of justice under the same, it shall be lawful for the President, and it shall be his duty, to take such measures, by the employment of the militia or the land and naval forces of the United States . . . for the suppression of such . . . domestic violence or combination."

26 Stat. at L. 200, sec. 1: "Every . . . combination in the form of trust or otherwise, or conspiracy, or restraint of trade or commerce, among the several States, or with foreign nations, is hereby declared to be illegal."

Sec. 4. "The several circuit courts of the United States are hereby invested with jurisdiction to prevent and restrain violation of this act, and it shall be the duty of the several district attorneys of the United

States . . . to institute proceedings in equity to prevent and restrain such violations."

The origin of the present difficulty is that certain mechanics who have been in the service of the Pullman Company are unwilling to work for the wages offered by the company, and claim that the company can and should offer higher wages.

The employers refuse, and the general sympathy for the unfortunate mechanics, whose share of the general hard times upon us all is conspicuous, has engendered in the minds of great numbers of working people in their neighborhood a desire to punish the employers, or compel them by some infliction to offer more wages.

Now, it happens that these employers—the Pullman Company—own a large part of those traveling conveniences on the railroads throughout the country which have become an indispensable comfort for all, and a necessity for women and children, upon long journeys; and these conveniences—the sleeping and dining cars, with the porters and attendants provided by these owners, the Pullman Company—are run by the railroad companies all over the country under continuing contracts made between the railroad companies and the Pullman people. The point at which the retaliation of the sympathizing workmen has been adroitly aimed is to induce the railroad companies to break their contracts with the Pullmans, and thus render the Pullman car property unproductive. The trainmen, in great numbers, in effect, say to the Chicago railway managers, If you do not break your contracts with the Pullmans, we will no longer run your trains. In action they have gone beyond this, by violent obstruction of tracks and destruction of cars.

This is what, in private life, is called malicious interference with contract. If it were done by a few men, on a small scale, actions for damages would soon convince the wrong-doers that they had misconceived their rights. But it is done on so vast a scale that an action for damages would be as ludicrous as it would be to whip the boy whose forbidden playing with matches burned up the city of Portland. The great number of wrong-doers, and the obvious inadequacy of actions for damages, has practically made them feel quite indifferent to the law; and the disorder has spread day by day.

On July 3 the president ordered certain United States regulars to proceed to Chicago to enforce the observance of the laws, the United States Judge, marshal, and district attorney having certified to the President that, in their judgment, it was impracticable to otherwise execute the orders of the court. This step is authorized by the United States Revised Statutes, section 5,290.

Under the date of July 5, Governor Altgeld, of Illinois, wired a protest to the President against his ordering the Federal troops into service at Chicago—the governor claiming that the State can take care of itself, and, being amply able to enforce the law, the interference of the Federal troops is unauthorized. He stated, as the reasons for suffering the disorders to continue, that the accounts given were exaggerated, and that no one had asked him to interfere. The President replied:

"Federal troops were sent to Chicago in strict accordance with the Constitution and laws of the United States, upon the demand of the Post-Office Department that obstruction of the mails should be removed, and upon the representations of the judicial officers of the United States that process of the Federal courts could not be executed through the ordinary means, and upon abundant proof that conspiracies existed against commerce between the States.

"To meet these conditions, which are clearly within the province of Federal authority, the presence of Federal troops in the city of Chicago was deemed not only proper but necessary, and there has been no intention of thereby interfering with the plain duty of the local authorities to preserve the peace of the city.

GROVER CLEVELAND."

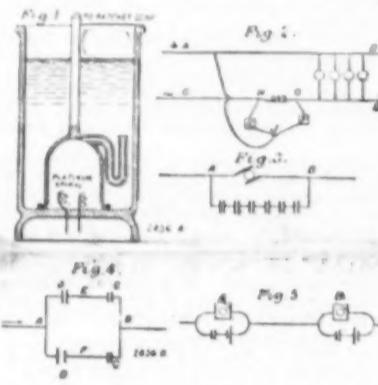
The President deserves the highest commendation, in these times of truimph and time-serving policies, in acting upon the line of his constitutional and sworn duty. It is not the place of an American executive, sworn to enforce the laws, to sit still in the face of even exaggerated accounts of public disorder, and plead that he is able to quell it, but no one has asked him to do so. He should be moved by his oath, even if the crowd ask him not to interfere.

So far as the misguided men who are combining in these lawless contests are concerned, it seems plain that they have much to learn. They have tried the power of combination, and have found it great. They are now about to try the power of the law, and they will find it far greater. The American people have not enjoyed liberty and self-regulated order these four generations for nothing. They will maintain their inheritance and will support the hands of their chief magistrate and commander-in-chief to the very last. The experiment that the strikers are trying is a very inconvenient one to the country. It cannot be other than a painful and disastrous one to themselves, their families, their industries, and their city. But the lesson seems needed, and good citizens can only hope that it will be taught as effectively as the stoppage of violence requires.—*The Outlook.*

SOME APPLICATIONS OF ELECTROLYTIC CELLS.

It is well known that the cost of meters has always been a most serious item in the expenditure of electric light companies, particularly if meters of the dial type are adopted, in which a customer can read off his consumption just as in a gas meter. In many cases this expenditure has been as much as 3 per cent. of the total capital account, and most of these meters are, in addition, somewhat delicate pieces of mechanism, requiring a considerable amount of looking after. We recently had an opportunity of inspecting, says *Engineering*, a meter now being introduced by the Waterhouse Electrolytic Syndicate, Limited, of 33 Old Broad Street, London, E. C., which should be extremely cheap to construct, and of unimpeachable accuracy, while at the same time the meter has the great practical advantage of recording the total current used on a dial just as a gas meter does. It is well known that if a current is passed through a voltmeter the quantity of gas generated is proportional to

the time integral of this current. It is on this long established principle that the Waterhouse meter is based, but the distinguishing feature of the instrument is the extremely simple means by which the gas generated is accurately measured. Two short platinum spirals are fused into the bottom of a long and narrow glass vessel (see Fig. 1), and are connected to leading in wires in the ordinary way. Over these is placed a glass bellmouth, having a long stem connected to a ratchet mechanism actuating the wheel work of the meter. As the current flows, the gas fills the bell-mouth, causing it to float up and actuate a ratchet gear. At the same time the water level in the inverted siphon, shown to one side of the bellmouth, is lowered until finally the bottom bend is passed, when the whole of the gas in the bellmouth is immediately discharged through the siphon. This done, the bell-mouth falls to the bottom of the vessel again, ready to receive a fresh charge. Careful experiments are stated to have shown that the time required to fill and discharge the bellmouth is constant at least one second. In practice two of these elements are used, the connections being as indicated on Fig. 2. In this diagram, A B represents the positive main and C D the negative main. The two voltmeters are coupled together and to this negative main, as shown, a resistance, G H, being placed between the points in which they are connected to the negative main such that under full load there is a drop of $\frac{1}{2}$ volt between the points, G H. The point, J, is connected to the positive main, as shown. When all the lamps are cut out, a small current flows from the positive main through the voltmeters to the negative main. The resistance on this circuit is 1,200 ohms, and so on a 100-volt circuit this waste current is only $\frac{1}{12}$ ampere. The resistances in the two voltmeter circuits are so adjusted, once for all, that under these conditions the bellmouth in each fills and discharges in the same time. These two bellmouths are connected by a differential gear to the same dial, so that when both fill at the same rate they counteract each other's action on the dial, the hands of which accordingly remain stationary. Suppose now a lamp is switched on. Then the potential of H is lowered with respect to G, and hence a stronger current flows through the voltmeter, E, than through F. The bellmouth on E is now filled quicker than its fellow, and the dial hands are moved correspondingly. If still more lamps are switched in, E gains still more



on G, its gain being registered on the dial, as already explained.

In addition to the above use of the electrolytic cell, Mr. Waterhouse proposes to use it as a sort of "safety valve," if one may use the term. Thus, suppose it is required to drive a motor from a lighting circuit. The motor is placed in the circuit as shown at A B, Fig. 3, while a series of electrolytic cells are arranged as a shunt to the same circuit. The resistance of these cells is made very small compared with that of the motor. As long as the potential difference between A B does not exceed the back electromotive force of the electrolytic cells, no current can pass through these cells, but must flow through the motor. Should the potential rise, however, the back electromotive force of these cells is overcome, and the extra current, instead of flowing through the motor and burning out its armature, flows through the low resistance circuit formed by the cells. As will be seen, as long as matters are going right, no current is wasted through the cells. By means similar to this Mr. Waterhouse claims to have maintained a potential constant within $\frac{1}{4}$ per cent. on a circuit worked by a dynamo of which the speed of running varied 50 per cent.

A still further application of the cell is continuous current effects from an alternating circuit. The method adopted is shown diagrammatically at Fig. 4. The circuit through which an alternating current is passing is split at A B. In each of the branches is placed an electrolytic cell, C, and a battery, D, the connections being such that if the electromotive force of the batteries was high enough, a constant current would flow around the circuit. A E B F. The electromotive force of the batteries is, however, insufficient to overcome the resistance of the electrolytic cells, and hence when there is no current in the main line, no current flows in the circuit, A E B F. Now consider a wave of current flowing in the main in the direction shown by the arrow. The electromotive force of this will add itself to the electromotive force of one of the batteries, but will oppose that of the other. In consequence of this, the back electromotive force of the electrolytic cell in one branch will be overcome, while no current will flow in the other branch. When the direction of the primary current is reversed in the main, the reverse of this will take place. Thus it will be seen that all currents in one direction will flow through one branch and all currents in the other direction through the second branch, and hence a continuous current only will be found in each branch. It will be obvious that the potential of the alternating current must not be great enough unassisted to overcome the electromotive force of the electrolytic cells, but must only be able to do so when assisted by the batteries.

As a final example of the use of these cells, Mr. Waterhouse's system of duplexing may be described.

The arrangements are as shown in Fig. 4, where A and B represent electric bells, for instance. Each of these bells, it will be seen, is shunted with a battery and electrolytic cell, the electromotive force of these being such that normally no current passes. Suppose a current sent through the line in one direction, then this will assist one of the batteries and act against the other one. Hence a current will pass through one shunt circuit, short-circuiting the corresponding bell, while none flows through the other shunt circuit, but has to pass through the bell there, which it rings. Thus it will be seen a current in one direction will ring one bell, while one in the other will ring the other bell.

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TABLE OF CONTENTS.

	PAGE
I. ARCHAEOLOGY.—Assyrian Sculpture at the British Museum.—By GEORGE CLINCH.—An account of the sculpture obtained at Nineveh and other Assyrian cities.	1547
II. BIOGRAPHY.—The Work of Hertz—Microphonic Detectors, etc.—A continuation of Prof. OLIVER LODGE'S interesting resume of the work of Hertz in electricity and optics.	1548
III. PHYSICS.—The Discovery of the Hertzian Rays.—By H. RAYLEIGH, Professor of Natural Philosophy, Royal Institution.—A brilliant paper on the discoveries made by Prof. Tyndall in light, heat, and electricity.	1548
III. BOTANY.—HORTICULTURE AND ARBORICULTURE. The Bamboo—Wan-Loo's Composition.—By ELIZABETH CUMINGS.—An interesting article, written in the form of a Chinese boy's composition, but which, nevertheless, conveys much information on this interesting substance.	1548
IV. BOTANY.—A Chat on Orchids.—By MRS. N. PIKE.—A paper on the growth of orchidaceous plants.	1548
V. BOTANY.—Passiflora Manicata.—The red flowered passion vine which was introduced into California from Peru.—Illustration.	1548
VI. CHEMISTRY.—Rose-Green Soap.—By N. MARSH.—A long paper, giving the reasons for the high estimation in which this soap is held, and describing the culture of roses on scientific lines. 3 illustrations.	1548
VII. EDUCATION.—L'École Polytechnique.—A description of the celebrated French school of engineering. Interesting details of the life and methods of instruction adopted at the school. 3 illustrations.	1549
VIII. EDUCATION.—Helen Keller.—By KATHARINE D. PARTRIDGE.—Details of the remarkable performances of a child whose sight and hearing was lost at an early age.	1549
V. ELECTRICITY.—Some Applications of Electrolytic Cells.—Illustration.	1549
VI. MILITARY ENGINEERING.—Portable Trenching Tools for Infantry.—By Lieut. W. C. WREN, Fifth United States Infantry.—A description of the various trowel bayonets, trenching spades, etc., used in various armies of the world. 6 illustrations.	1548
VII. MINING.—American "Tripoli."—By E. O. HOVEY.—Description of the American quarry at Seneca, Mo.—A large business has been done in the stone from the discovery of bed of this polishing material.—Illustration.	1548
VIII. MISCELLANEOUS.—The Legal Aspects of the Dispute at Chicago.—By AUSTIN ABBERY, Dean of the New York University Law School.—A selection from the statutes bearing upon the recent labor difficulties.	1549
IX. MISCELLANEOUS.—Typhoid Fever, in memoriam.—A humorous inscription for a death-dealing drinking fountain.	1549
X. PALEONTOLOGY.—Footprints of Vertebrates in the Coal Measures of England.—By O. C. MARSH.—These fossil footprints are now in the museum of Yale University. 5 illustrations.	1549
X. PHOTOGRAPHY.—Instantaneous Photograph of a Kicking Horse.—Illustration.	1548
XI. PHOTOGRAPHIC RELIEFS FOR DECORATIVE OR ORNAMENTAL USE.—This article describes a simple process for producing reliefs photographically by means of bichromated gelatin.	1548
XII. TECHNOLOGY.—Lard.—By H. W. WILEY, Chemist to the U. S. Department of Agriculture.—A paper on the physical properties of lard, yellow grease, stearine, etc.	1548

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